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NO. LXXIII.—JANUARY, 1875.—VOL. XII.

AGGRESSIVE TORPEDOES.

From "Army and Navy Journal."

It appears that the constructor of the Whitehead Torpedo has recently modified his system in order to attain a very high rate of speed—the only possible expedient by which the disadvantage of not possessing any directing power can be, to some extent, met. Obviously the deviation from the intended course resulting from currents and other disturbing causes, after pushing out the torpedo, will be diminished in the inverse ratio of the speed of the submerged body. And, of course, the chance to strike an antagonist in motion will be greater in proportion to the increased speed of the torpedo. But, unfortunately, great speed cannot be produced without resorting to such a form that the efficiency of the weapon will be seriously impaired, if not destroyed. Bearing in mind that the power necessary for propulsion increases as the cube of the velocity, we need not be surprised to find that the length of the improved "fish" torpedo has been augmented to nineteen feet, while the diameter has been reduced to fifteen inches. Nothing short of such disproportion of length and diameter admits of lines sufficiently sharp to enable a submerged body to be propelled at the extraordinary rate of speed which, agreeable to the reports of our officers on the Austrian coast, has recently been attained by the Whitehead torpedo. Nor could such speed be produced, notwithstanding the sharp lines employed, and the consequent sacrifice of necessary capacity, unless the submerged body were charged with compressed air of a tension which experienced engineers regard as dangerous. Recent accidents in Europe prove that an expansive force of one thousand pounds to the square inch, now employed by Whitehead, is not safe even for experimental purposes. But let us assume that workmanship and materials have arrived at such a state of perfection that we may safely handle the "fish," whose skin, agreeable to reports furnished to the Bureau of Ordnance, is only one-eighth of an inch thick, and whose interior is charged with air exerting a pressure of 1,000 pounds to the square inch. The important question then presents itself: will the new instrument prove sufficiently destructive to sink a modern iron-clad ship? The report referred to states that the explosive charge of the Austrian torpedo consists of sixty-six pounds of gunpowder, placed, of course, in the forward end of the body, where, owing to its pointed form, the charge will occupy a length of nearly four feet. Hence, as the force of explosive substances contained in elongated vessels acts at right angles to the longest axis, it will be evident that the force of the long, taper, conical charge of the improved Whitehead torpedo—supposing that it strikes fair—will be exerted in lines nearly parallel to the skin of

CAPTAIN ERICSSON'S AGGRESSIVE TORPEDO SCALE, ONE QUARTER OF AN INCH TO THE FOOT.

See Page 1.

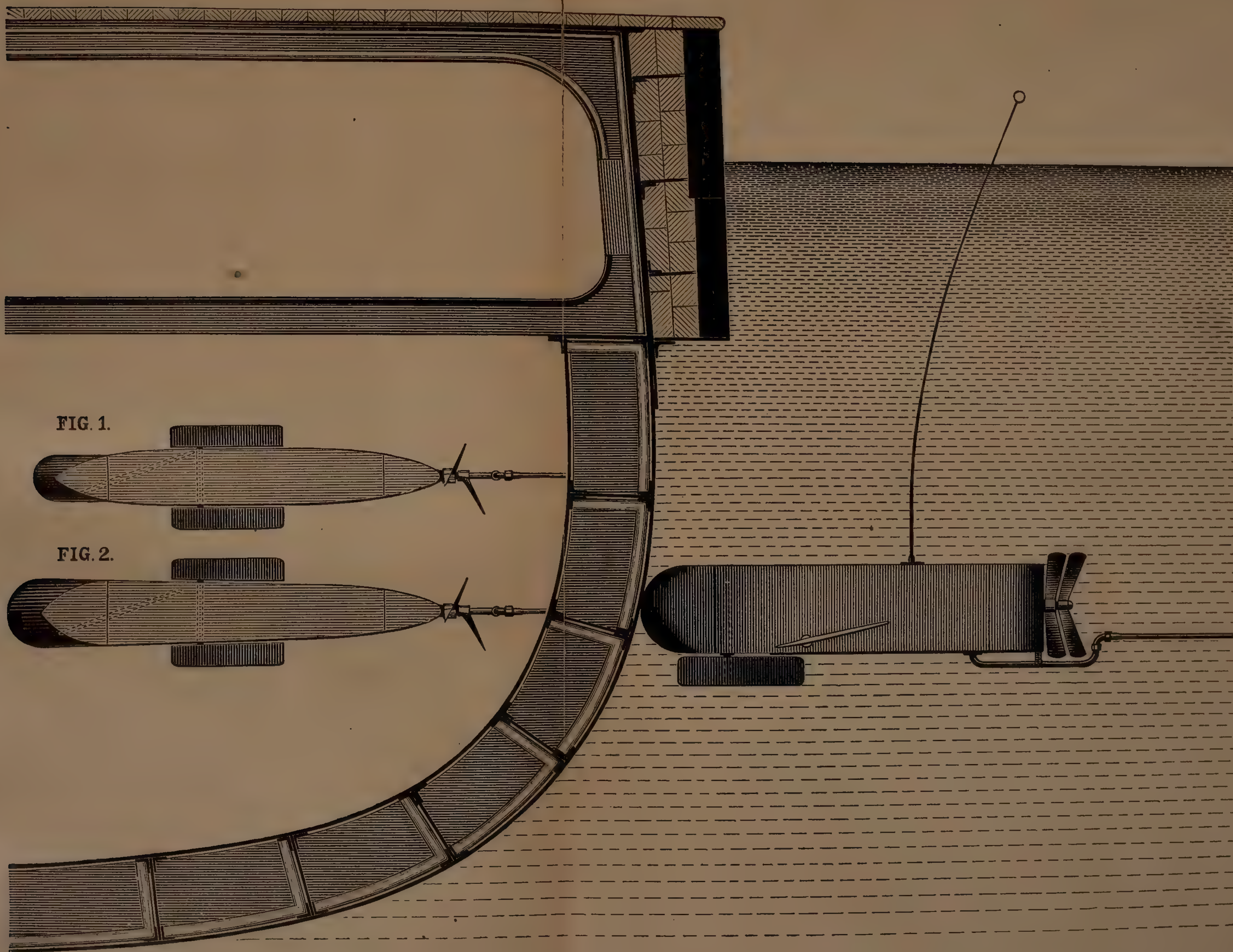


FIG. 1.

FIG. 2.

the vessel struck. Apart from this grave circumstance, the fact should be considered that the charge is of conical form, and that therefore the distance of the centre of gravity of one-half of its mass is situated only one-sixth of its length from the base. Consequently, at the moment of ignition, fully one-half of the explosive energy will be wasted by expansion into the empty body of the torpedo, while the other half, acting at right angles to the axis of the torpedo, will, as before stated, exert its force in lines nearly parallel to the ship's side, and thus become partially harmless. Again, the portion of the charge near the apex of the cone, though in contact with the body struck, is too small in volume to exert destructive force.

The foregoing considerations point to the fact that the expedient of making aggressive torpedoes, long, slender and pointed, in order to attain high speed in spite of the limited amount of motive energy which can be stored within their contracted bodies, is incompatible with destructive efficiency. No system which does not admit of carrying a very heavy explosive charge, of such a form that the centre of gravity of the same is nearly equidistant from its outward limits, will prove adequate to destroy iron-clads constructed on the admirable cellular plan of the Inflexible. Unless, therefore, some new motive agent can be procured many times more powerful for the space it occupies, than atmospheric air compressed, the tubular-cable system must be resorted to, since that enables us to propel a body of sufficient capacity to carry an explosive charge of sufficient magnitude. Nor should the all-important fact be lost sight of, that the tubular-cable system enables us to control and direct the course of the torpedo. Regarding the proper form and size of the vessel which contains the explosive charge, we need hardly observe that, hitherto, that subject has received too little attention.

The reader will find an illustration on the front page, prepared from a drawing which Captain Ericsson has furnished to enable us to discuss the question of form and magnitude of charge, without entering into an elaborate disquisition. The section of the ship represented which the aggressive torpedo is supposed to strike, will readily be recognized as that of the British iron-clad Devastation. Fig. 1 shows the top view of a torpedo carrying a charge of 400 pounds of nitroglycerine. Fig. 2 shows the top view of another torpedo of nearly similar form, carrying a charge of 1,000 pounds of the same explosive substance as the former. The slight difference in size of the two torpedoes will probably surprise those who do not reflect on the fact that, while the areas are as the square of the lineal dimensions, the contents is as their cube. Having in former issues of the "Journal" minutely described the Ericsson torpedo, we need only remind the reader that the rudder is placed under the bow of the submerged body, and that the horizontal rudders, or fins, for regulating the submersion, are placed one on each side, nearly amidships. The propellers, tubular cable, and wire mast, with the colored ball at the top, for indicating the position of the torpedo, require no further description. The blunt form of the bow will no doubt be objected to by naval architects on account of the attendant increased resistance. In answer to this objection it suffices to state, that the unlimited amount of motive energy supplied through the tubular cable, renders the resistance of the torpedo of no account. Referring to fig. 2, it will be found on applying the scale, that the centre of gravity of a charge of 1,000 pounds is situated less than twenty inches from the skin of the iron-clad ship. Experts are aware that the explosion of such an enormous charge, in actual contact, especially as the mean distance of its mass is only twenty inches from the point struck, possesses adequate force to destroy iron-clad ships of any form whatever. It is hardly necessary to observe, that the cellular system will be of no avail if the force of the explosion be sufficient to break the ship partially in two. Possibly the constructor of the Inflexible is prepared to show that a charge of 1,000 pounds of nitro-glycerine is not sufficient to produce such an effect. If so, he will do well to consider that the tubular-cable system admits of doubling or quadrupling the stated charge.

THE FUTURE OF WAGES AND OF IRON.

Remarks of Hon. Abram S. Hewitt, at the Bell-Whitwell Dinner, December 10, 1874.

Mr. President and Gentlemen: Entirely satisfied as you must be after this bountiful repast with all things here below, unless it be the price of iron, I am, nevertheless, quite sure that you will be ill content with me if I were to defer for one moment the words of welcome to our cherished guests, Mr. I. Lowthian Bell and Mr. Thomas Whitwell, which spring unbidden from the heart of every member of this goodly company of their fellow ironmasters, assembled to do them honor and to assure them of our profound respect and hearty good will. I will not attempt to disguise from them, as they surely will not disguise from themselves, that this assemblage is of no common character and implies no ordinary compliment. They are to-night the honored guests of the whole American iron trade, and we rejoice that this opportunity is afforded to us to testify the high estimation in which they are held, and through them to acknowledge the great debt of gratitude which we in common with all the world owe to the land which gave them birth, for its numerous and inestimable contributions to the development of the production of iron in modern times.

We honor Mr. Bell because he has done so much to make the iron business honorable. The son of an ironmaster, he inherited a position in the trade which might have satisfied his ambition without any special effort for its improvement; but from his early youth he carefully prepared himself for the intelligent administration of a great business by scientific training at the best schools, and by patient investigation of the principles which underlie the intricate processes of manufacture. Fortunately, perhaps, for himself and the world, his career has been identified with the most marvellous growth of productive industry—that of the Cleveland iron region—of which history affords us any knowledge; and to this development he has largely contributed by his intelligence, his scientific training, and his rare powers of patient investigation. By these labors he has fairly won for himself the highest position which, in our special department of industry, can be attained by any man, that of President of the British Iron and Steel Institute, the most enlightened and powerful organization for the advancement of a purely industrial interest which any nation has yet devised. In the course of his labors he has instituted an exhaustive series of experiments upon the operations of the blast furnace and its chemical phenomena, the results of which he has embodied in an elaborate treatise, which is justly regarded as the most valuable contribution in our day made to the laws governing the smelting of iron, and leaving but little to be done in that direction by future investigators. While his successful acquisition of knowledge, and the practical skill wtih which he has applied it to useful purposes, would entitle Mr. Bell to very great and deserved distinction, to us his chief merit lies in the fact that he has not kept his acquisitions to himself, or even to his own country, but has made haste to share with all the world the useful results of his labor, thus taking himself out of the category of a mere man of business laboring for his personal advancement, and enrolling himself among the benefactors of mankind. And to Americans he has a special claim to interest, not merely that he has his home at "Washington, in the county of Durham," whence came the family of the "Father of his Country," but that he dispenses there a generous hospitality, which makes the patriotic pilgrim and the wandering ironmaster feel that they have returned to the home of their ancestors. For such deserts the welcome which we offer here to-night is indeed all too poor.

We honor Mr. Whitwell because he also demonstrates the truth, which the world has come at last to admit, that the highest science is necessary to insure the greatest economy in manufacture. His careful training as a mechanical engineer undoubtedly gave him special advantages for a successful career as an ironmaster. By his energy, enterprise, and willingness to test fundamental principles in practice, he has contributed in a marked degree to the cheapening of the cost of iron, and has therefore entitled him to the thanks of all who are interested in the progress of civilization throughout the world. He is, so far as we are concerned, fortunate in having identified his name with the word "stove," which in America is always associated with the pleasant memories of "home." But his true title to the respect of mankind rests upon the fact that he has taught the world how to economize fuel, and is therefore a conservator of force. His benefaction is direct and positive, and the measure of it is the number of tons of coal which will annually be saved to mankind by his invention. We might even venture upon a computation of his contribution to the wealth of this continent; but I fear that the result would be a sudden conviction on our part of the inadequacy of such honors as we pay to him to-night to discharge the obligations under which he has placed the iron industry of two continents.

To such men as Mr. Bell and Mr. Whitwell, distinguished leaders in the great army of modern industry, too much honor cannot be done; and yet, with all their personal claims to our respect and affection, it will derogate nothing from the compliment we have tried to pay them, if I say that these claims alone, strong enough as they are to open to them the home and heart of every ironmaster, would not of themselves have been sufficient to produce this collective and unique demonstration in their honor. To us they are more than members of the same fraternity: they are representative Englishmen, citizens of a country to which the iron trade may be said to owe, if not its existence, nearly all the great inventions and improvements which have enabled iron to be produced in quantity and at a cost essential to the growth of society and progress of civilization. To Great Britain the world owes the application of mineral coal to the smelting of iron ores; the invention of the puddling process and of grooved rollers; the introduction of the hot blast; the steam hammer; the Bessemer process; the Siemens regenerative furnace; the Whitwell stove; the steam engine, locomotive and stationary; contributions which, taken away, would relegate the world to a condition of barbarism which the imagination refuses to contemplate.

We cheerfully recognize the primacy of England in the domain of industry; and we are justly proud that we belong to a race which in the pursuit of material ends has used them as the means of asserting the right of man to free government and of establishing social order upon the eternal principles of truth and justice. We recognize that, as in the world of industry, so in the domain of politics, she has taken no step backward, and we have learned from her history, which belongs equally to us, that every new invention introduced, and every just political principle established, improves the condition of the working classes, and adds to the fund available for their better remuneration. While we look with wonder on the mechanical and industrial achievements of Great Britain during the last hundred years, we feel that our admiration is rather due to the steady progress which has been made in bettering the condition of the working classes and to the increase of comfort which they now enjoy, as the result of a better application of the natural forces and wiser legislation based upon sound economical principles. The steady rise of wages measured by their purchasing power in Great Britain, during the last quarter of a century especially, is the most encouraging feature in the history of mankind—a very rainbow of promise to the patient sons of toil throughout the world, because by comparing the past with the present the beneficent influence of sound legislation on the welfare of the working classes thus becomes a matter of absolute demonstration. The abolition of the Corn Laws I regard as the turning point in the welfare of the industrial classes throughout the world, because it was a practical recognition in its most enlightened nation that the supposed interest of special classes, even when they govern, must yield before the force of public opinion, to the just claims of the governed. The immediate result of this change in British policy was and continues to be a very decided increase in the substantial remuneration paid for daily labor.

But an advance of wages where there is no previous training for their proper use is not necessarily a benefit; and after years of experience public sentiment in Great Britain has arrived at the conclusion that the general education of the masses is essential for their steady progress towards a higher social plane. And it seems to me that the step which has been recently taken in England towards the compulsory education of the masses, in spite of the opposition of selfish interests seeking to retain their hold upon mere muscular force, to the exclusion of mental development, will add enormously to the productive value of the workingman, and enable him to secure a rate of compensation justly due to such increased value. There may be those who falsely look upon a rise of wages in Great Britain, as the result of this better training, with apprehension, and who predict that the supremacy of British industry will in consequence of the improved condition of the working classes pass away; but it is to the honor of William E. Forster, whose presence here we hoped to have to-night, that with the true instincts of a statesman, such as he exhibited when he was the eloquent champion of the American Union in the time of its peril, he was able to discern in the history of British legislation in its effects upon British industry the fundamental law that labor is productive in proportion to its intelligence, and that no more certain means could be devised for perpetuating the supremacy of Great Britain over other nations than by securing for the masses of the people a better education and a higher culture.

For the same reason the establishment of the British Iron and Steel Institute marks a new era in the international history of industry. While it is true, as Mr. Bell justly remarked in his presidential address at Liege, "that art and science recognize no geographical or political boundary," it is equally true that prior to the formation of the Institute the "secrets of the trade," as they were called, were jealously guarded, and access to works where special processes were carried on was extremely difficult, and often impossible, as well to foreigners as to natives. For the first time in the history of industry, the accomplished leaders of a great trade associated themselves together, not merely for the purpose of instructing each other in their special departments, of comparing experience, and of gathering together the latest discoveries in science and art for mutual benefit, but, with a liberality never before evinced except by scientific bodies, and which cannot be too highly commended, all the world was made free to partake of the advantages of this organization, so characteristic of the catholic spirit which happily is beginning to mark our age. The beneficial results of this wise policy are already apparent in the general introduction throughout Great Britain of the best machinery and the most economical processes, whereby the cost of producing iron has been cheapened, alike benefiting the consumer and increasing the ability to pay better wages to the operatives engaged in its production.

Not inferior in importance to the general advance in the British iron trade resulting from the establishment of the Iron and Steel Institute is the introduction and successful establishment in England of the principle of arbitration for the settlement of disputes between the employer and the employed as to rates of wages. While it cannot yet be said that the disastrous consequences resulting from strikes have been altogether averted, every intelligent man now sees that their occurrence is rendered more difficult, and that the good understanding between masters and men, so indispensable to the successful conduct of business, must be greatly promoted by the discussions and evidence which the contending parties are bound to have before an impartial umpire. Arbitration not only pours oil upon the troubled waters of industry, but in fact *is* oil to the machinery of trade, keeping it in motion without jarring and stoppage from unnecessary friction. When the working classes come clearly to understand how the fund available for the payment of wages is lessened by strikes and lock-outs, they will regard them as the greatest evils of the age, and, in this and every country where they enjoy the right of suffrage, will insist that the principle of arbitration in trade disputes shall be incorporated into the legislation of all industrial countries, and thus relieve themselves and the community from the dreadful suffering and irreparable losses resulting from any protracted stoppage of the machinery of production.

Great Britain also has the merit of having originated International Exhibitions of Industry, which in the judgment of all intelligent men have done more for the rapid progress of civilization than any other human agency; and for the working classes especially have been of incalculable benefit, not merely in the enlargement of their ideas, and the development of their tastes, but in patiently gathering together the facts which affect their social condition; the rates of wages paid in different countries; the elementary means of education adapted to their wants; the dwellings in which they are, as compared with those in which they should be housed; the varieties of food and the methods of its preparation; all of which have exerted an influence throughout Europe, and especially in Great Britain, which no lover of his race can overlook, and no statesman can afford to disregard. We are now about to avail ourselves of this grand humanitarian idea in our own country, and we are glad to learn by the cable to-day that Great Britain will take part in our Exhibition in 1876, the result of which must be the increase of national good will and an exchange of ideas which cannot fail to advance the interests of labor on both sides of the Atlantic.

In this connection there is another phase of recent industrial development in England as well as in this country which should attract the notice of all thoughtful men, in its bearing upon the question of the economy of production, and the consequent augmentation of the wages fund. I refer to the steady growth in the size and completeness of the establishments devoted to the production of iron, and, from the magnitude of the capital necessarily employed, their consequent transfer from individual to corporate ownership. Without entering into the question of the comparative advantage of these respective kinds of proprietorship, I desire to direct special attention to the facility which these corporate bodies offer for interesting the workmen directly in the ownership and the profits of the business; which, if generally availed of, must result in the final extinction of strikes and labor disputes, and thereby largely increase the earnings of the working classes, measured not by the day, but by the lifetime, and improve their moral and social standing. Now, Great Britain, in her corporate manufacturing companies, such as Crossley's, and in her legislation, which makes legal provision for "partnership of industry," has set us an example of wise foresight, which we have, I confess, been slower to follow than could have been anticipated, but possibly to be accounted for by the fact that these fine adjustments of conflicting interests are more necessary and feasible in older and more densely populated countries than in a new world like ours, where, as yet, the forces of nature have been appropriated only to a moderate extent. Nevertheless the example is before us, and we recognize that to us Great Britain is a great free school of industry, in which have been wrought out for us without cost the wisest institutions, the most complete machinery, the best processes, and the most advanced organizations for the conduct of industry which the experience of a free and enlightened nation overflowing with capital and energy has been able to elaborate.

You, gentlemen, and our distinguished guests will, I am sure, pardon this enumeration of the phases of industrial and social progress especially apparent in the British iron trade, in view of the supreme importance to us here of the question of wages, and, above all, of the ability of Great Britain to pay a steadily increasing rate of wages, an ability which she is thus surely augmenting by the discoveries of her men of science and the inventions of her mechanics, by her wise and progressive legislation, looking to the future education and moral elevation of her working classes, to the settlement of all trade disputes, and to the reconstruction of her industry on the enduring basis of practical harmony between labor and capital. Every step in this direction is a benefaction to the United States as well as to Great Britain, and drives another nail into the coffin of international restrictive legislation; and no one will hail with more enthusiasm than this body of American ironmasters and their distinguished guests the advent of the day when all barriers to free commercial intercourse between the nations can be safely removed, by the equalization of the wages of industry which the enlightened statesmen and scientists of Great Britain have done, and are doing, so much to bring about.

And this beneficent result cannot come too soon for the interest of the world at large. Although the business of making iron is everywhere passing through a stage of great stagnation, yet its future growth can be predicted to almost the same certainty as we have learned to calculate the orbits of the heavenly bodies. In 1856, when the annual production of the world was about 7,000,000 tons, after a careful investigation I ventured to predict that the production of iron would reach fourteen millions of tons in 1875. This limit was passed last year, when the product reached fifteen millions of tons. I do not think that I risk my character as a prophet when I indulge the belief that by the close of the present century twenty-five millions of tons per annum will be required to supply the wants of man. There are gentlemen in this room who will live to see this prediction verified, for it covers only the life of a single generation. Great Britain, in 1856, furnished one-half the annual supply, and she has been able to maintain this ratio till the present time. But even Mr. Bell and Mr. Whitwell, with all their natural confidence in the resources of the mother country, will admit they will be tasked to the utmost to keep up with the increasing demand for iron, at its inevitable rate of progress, when the total aggregate shall go beyond twenty millions of tons. Between Great Britain and ourselves, therefore, all possibility of rivalry must in the very nature of things soon pass away, and we shall then behold the magnificent spectacle of the two greatest and freest nations in the world co-operating together for the extinction of ignorance, pauperism, and crime, and the elevation of the working classes throughout the world to that condition of comfort and intelligence to which they have a just claim, and which no political system can deny without laying the foundation of its own ruin.

We have a common language; we inherit from England our common law and a priceless literature; we have governments based upon the same political rights of man, and the equality of all men before the law; we have the same social customs and standards, and the same love of home and the sanctity of the family relations; we have the same great end in view in the amelioration and enlightenment of the working classes; and, as if to provide us with the means of the speedy accomplishment of the hopes of all good men, we have, in the main, the control of that great fund of wealth and power which has been stored up in the coal fields, and which is the key to the progress of civilization and the improvement in the condition of mankind. We are in fact but one family, endowed with the same training, occupied in the same pursuits and aspirations, and blessed with the same moral and material resources. We are working to a common end, and by the unchangeable laws of nature we can work to no other; and hence it is impossible for any intelligent man not to see that the laws which govern production, distribution, wages, and profit must sooner or later operate with absolute equality and freedom between the two nations—if not between the continents; and hence whoever is engaged in the promotion of this desirable result, whoever hastens its advent by a single day, is the benefactor of this country, and should be its welcome guest.

Hence, Mr. Bell and Mr. Whitwell, we justify to ourselves, aside from personal grounds, this exceptional demonstration in your honor. You stand here to-night as representatives of England, our motherland, fruitful now as of old in good works and good examples, ever progressive in the development and application of the eternal principles of truth and justice; striving still, as in the days of King John and Charles the First, and James the Second, to elevate the masses of the people to a better condition—foremost in the march of industry and of civilization; and by the ties of blood and race, and in the possession of the joint estate of the coal and iron of the world, partners inseparable with us in the future benefactions to mankind which nature has put it in our power to confer.

Although commanded to speak words of "welcome," Mr. Bell and Mr. Whitwell, I am but too well aware that they are in reality the language of "farewell." Hence I have refrained from referring to the special facts of our development in the manufacture of iron, which you have both carefully studied; and in regard to which you will doubtless express your judgment at the proper time. We might regret perhaps that your visit has found us in such depression; perhaps it may be more justly said in the throes of a new birth; but it has at least this advantage, that you see the old passing away and a new era of science and mechanical excellence fairly inaugurated. For the first time in our history, we have a capacity for producing iron in quantity adequate to our consumption in a normal state of affairs, and when the old are fully adjusted to the new conditions, under which alone iron can be profitably produced, you will, I am sure, agree with me in one assertion, that it is the "manifest destiny" of this country to be the seat of an iron growth on a larger scale than the world has yet witnessed.

Gentlemen, in behalf of the American Iron and Steel Association, which has honored me with this privilege, because probably more than any other of its members I have enjoyed the boundless hospitality of the British ironmasters, I bid you "welcome and farewell," only in the hope that we shall be honored at our Centennial, in 1876, with the promised presence of the British Iron and Steel Institute, of which you, Mr. Bell, are the distinguished President, and you, Mr. Whitwell, are so eminent an associate.

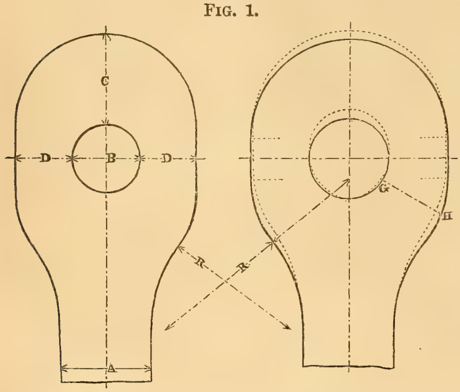
PROPORTIONS OF THE HEADS OF EYE-BARS.

BY CHARLES MACDONALD, C. E.

From "The Transactions of the American Society of Civil Engineers."

In the discussion of a paper on the proportion of pins, read by Mr. Bender, before the Society during the past year,* the importance of a properly proportioned eye-bar was referred to, as exercising a considerable influence on the size of the pin. Reference was had to the published account of experiments made in England, up to the year 1869, from which it appeared that in order to secure the full strength of a bar it is necessary to proportion the head according to the dimensions given in Fig. 1. The method observed in the manufacture of these heads is not stated in the published account of the experiments, but it is presumed that the bar is first rolled to the full width of the head, and then drawn down between the heads in a reversible mill to the required width, leaving the heads to be forged to the proper shape under a hammer. The results of the following experiments confirm the general accuracy of the English standard, and an examination of the change in form of the head under strain will be of interest in assigning reasons for the conclusions arrived at.

FIG. 1.

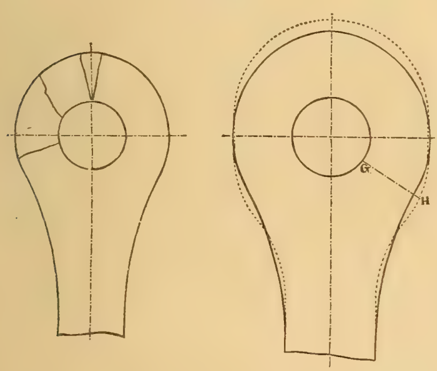


The tests were made at the works of the Watson Manufacturing Company of Paterson, N. J., during the month of December last, under the direction of Mr. O. Chanute, for the purpose of determining the character of the iron used in links for the new iron bridges on the Erie Railway. The testing machine was a hydraulic press of approved construction, and the behavior of the iron was believed to be in the main satisfactory. The results in this particular will not be reported in detail, further than relates to the subject under consideration. The heads of all the bars tested were made at the works of the Phillipsburg Manufacturing Company, by the process known as die forging. The end of the bar is slightly thickened and drawn down to a wedge shape; a pile of scrap is then placed upon it, and the whole heated to a welding heat, after which it is drawn out under a steam hammer, and forged into the proper contour of the head by means of a vertical die, half of which is cut out of the anvil and half out of the hammer. Three bars having a section of 4 by $\frac{3}{4}$ inches and 6 feet long, were broken in the body of the bar, under an average strain of 54,400 pounds per square inch;

* "Proportion of Pins used in Bridges," by Charles Bender, C. E., read before the Society April 2, 1873, and afterwards published in an extended form.

all of the bars indicating the same condition of fracture as the specimen submitted. In each of these the heads were proportioned as in Fig. 2. After rupture the heads were found to assume the form indicated by the dotted lines; from which it would appear that the proper disposition of material upon a line G H is of the first importance, as tending to transfer strain from the bar to the back of the pin without undue concentration at the edge of the pin hole. If the amount of material upon this line were sufficient to prevent change of form, the lines of strain from the bar will arrive at the section D D in a direction parallel to the bar, and the area of this section would then not require to exceed that of the bar itself. In practice it is not possible to effect this result absolutely, as will be noticed in the movement in this particular head;

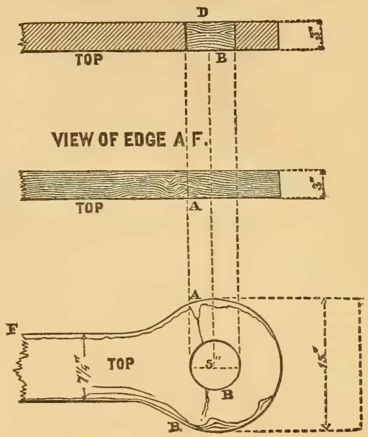
Fig. 2.



hence it is proper to increase that section by a certain proportion of the bar section; in this case it is 30 per cent., while by the English standard it is 25 per cent. In determining a proper depth behind the pin, it should be borne in mind that from the nature of the manufacture of a head the fibre of the iron cannot be disposed in the direction of the strain with the same uniformity on this line as elsewhere, hence the necessity of allowing a more liberal margin for safety.

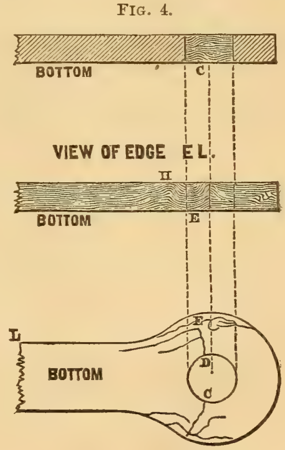
At the same time and place two bars were tested, having heads proportioned as in Fig. 3. No. 1 burst at the crown, under a strain of 44,000 pounds per square inch, the fracture showing burnt iron for a distance of $\frac{3}{4}$ inch inwards from the point. The broken head was subsequently removed, and a new one made from Passaic Rolling Mill iron, was welded to the bar by Watson's hollow fire process. Upon application of the

Fig. 3.



strain the bar broke through the Passaic iron with 51,600 pounds per square inch. No. 2 burst at the side of the head, on two lines, under a strain of 50,000 pounds, the fracture showing slightly burnt iron. It is to be regretted that the scantling of these last bars was not the same as in the previous cases, in order that the comparative effect of pin diameter might have been eliminated. If, however, a head be designed for a 4-inch bar upon the same basis as in Fig. 3, it will be found (see Fig. 4) that the section on a line G H

Fig. 4.



is considerably less than in the standard before you, and the depth behind the pin is also deficient.

The question as to whether the dimensions assumed in Fig. 2 are the correct ones for heads manufactured by forging or welding can scarcely be determined from the limited number of experiments referred to; but by comparing the results with those obtained upon the same subject abroad, it may be assumed that they approach very nearly to an accurate standard. One fact seems to be clearly indicated, namely, that it is not by increasing the section D D that stability is to be obtained, but by thickening the head in front of the pin in order to secure a proper distribution of strain in D D. Whether this rule applies to heads formed by the upsetting process, remains to be proved. The present practice in some establishments is to make D D 50 per cent. greater than the bar; probably to counterbalance the effect produced by distortion of fibre in the manufacture; and because of the difficulty of forcing the metal far enough back to maintain a proper width in front of the pin.

Inasmuch as the diameter of pin must first be known before the head can be proportioned, a table of pin diameters is annexed, varying for widths between 2 and 7 inches in flat iron, and up to $4\frac{5}{8}$ inches for squares and rounds. This table has been calculated upon the supposition that for flats thinner than $3\frac{1}{2}$ to 1, the pin diameter should be 75 per cent. of the width of the bar, as indicated by the English standard. But inasmuch as the experiments upon which this ratio was determined, were made with the pin supported on each side of the eye,* it becomes necessary to consider the effect of a thick bar upon a pin projecting as from the top chord casting of a bridge. For all practical purposes we may assume the pin to be in the condition of a cylindrical beam fixed in position at its supports and loaded with a weight equal to the strain upon the bar, distributed uniformly over a length of pin equal to the thickness of the eye. The formulæ expressing the diameter of pin which shall not be subjected to a greater strain upon its extreme fibres than 10,000 pounds per square inch, under the above circumstances, are as follows:

For flat bars—

$$D = 1.721\, t \sqrt[3]{n}, \qquad \text{(Eq. 1.)}$$

* The diameter of pin in the experimental bar was determined with reference to heavier bars in the structure for which it was intended.

In which t = thickness, and $t\,n$ = width. For square bars, $n = 1$. For round bars, in which the thickness of head is $\frac{1}{8}$ of an inch less than the diameter of bar, the expression becomes

$$D = \sqrt[3]{4\, d^3 = \tfrac{1}{2}\, d^2} \qquad \text{(Eq. 2.)}$$

In which D = diameter of pin, and d = diameter of bar.

By solving Eq. 1 for values of no greater than 3 1-2, it will be found that the value of D obtained will be less than 75 per cent. of the width of the bar; hence, for all widths above this limit, the ratio 75 must be taken as determining the pin diameter. For other widths the formulæ as above have been used in calculating the table.

Mr. Collingwood—Mr. Macdonald has pointed out two primary considerations in the economical use of iron—form and condition of the metal. Unless these are thoroughly cared for, the consequent result will be an increase of weight in our structures. Admitting, however, that these are as required, it seems to me that a third element should be taken into account (even in deciding upon the first) and that is, the methods pursued in forming eyes, bolts and the like—not, however, referring to the state in which the process employed leaves the iron, chemically considered (that is burnt or unburnt), but to its physical condition, its compactness and the uniformity of its fibre.

In preparing the lower anchor bars of the East River Bridge for insertion into the masonry, four bars were left in the acid a little too long, and the result was to show the fibre in the eyes very plainly. The bars were 3×7 inches, section, about 13 feet long from centre to centre of pin holes, which were 5 inches, and the eyes 15 inches in diameter. The eyes were formed by hydraulic pressure, being first upset on the end and then pressed on the flat into a die which gave the perfect shape. The two sides, edges and section of the iron in the pin-hole of one of the eyes are shown in the figures. The result of this process, as will be at once seen, is to cause the fibres to fold back upon themselves, and leave on each face (almost directly in the position pointed out by Mr. Macdonald as needing greatest strength) lines more or less depressed, the average depth being 1-16 to 1-32 inch.

DIAMETER OF PINS.

Thickness in Inches.	FOR FLAT BARS. Width of Bar in Inches. 2	2½	3	3½	4	4½	5	5½	6	6½	7	FOR ROUND AND SQUARE BARS. Diam. or side of Square.	For Round Bars.	For Square Bars.	Diam. or side of Square.	For Round Bars.	For Square Bars.
1/2	1 1/2	1 7/8	2 1/4	2 5/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1	1 9/16	1 3/4	2 3/4	4 5/16	4 3/4
5/8	1 5/8	1 7/8	2 1/4	2 5/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 1/8	1 3/4	1 15/16	2 7/8	4 1/2	5
3/4	1 7/8	2	2 1/4	2 5/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 1/4	1 15/16	2 3/16	3	4 11/16	5 3/16
7/8	2	2 3/16	2 5/16	2 5/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 3/8	2 1/8	2 3/8	3 1/8	4 15/16	5 7/16
1	2 3/16	2 3/8	2 1/2	2 5/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 1/2	2 5/16	2 5/8	3 1/4	5 1/8	5 5/8
1 1/8	2 3/8	2 9/16	2 3/4	2 7/8	3	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 5/8	2 9/16	2 13/16	3 3/8	5 5/16	5 13/16
1 1/4	2 1/2	2 11/16	2 15/16	3 1/16	3 1/4	3 3/8	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 3/4	2 3/4	3 1/16	3 1/2	5 1/2	6 1/16
1 3/8	2 11/16	2 15/16	3 1/8	3 5/16	3 7/16	3 9/16	3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	1 7/8	2 15/16	3 1/4	3 5/8	5 5/8	6 1/4
1 1/2	2 7/8	3 1/16	3 1/4	3 7/16	3 5/8	3 3/4	3 15/16	4 1/8	4 1/2	4 7/8	5 1/4	2	3 1/8	3 1/2	3 3/4	5 7/8	6 1/2
1 5/8	3	3 1/4	3 7/16	3 5/8	3 13/16	4	4 1/8	4 5/16	4 1/2	4 7/8	5 1/4	2 1/8	3 5/16	3 11/16	3 7/8	6 1/8	6 11/16
1 3/4	3 3/16	3 3/8	3 9/16	3 13/16	4	4 3/16	4 3/8	4 1/2	4 5/8	4 7/8	5 1/4	2 1/4	3 1/2	3 7/8	4	6 5/16	6 7/8
1 7/8	3 3/8	3 9/16	3 13/16	4	4 13/16	4 3/8	4 9/16	4 11/16	4 7/8	5	5 1/4	2 3/8	3 11/16	4 1/8	4 1/8	6 1/2	7 1/8
2	3 1/2	3 3/4	3 15/16	4 3/16	4 3/8	4 9/16	4 11/16	4 7/8	5	5 1/8	5 1/4	2 1/2	3 15/16	4 5/16	4 1/4	6 11/16	7 5/16
2 1/8	3 11/16	3 7/8	4 1/8	4 5/16	4 9/16	4 11/16	4 15/16	5 1/16	5 3/16	5 5/16	5 1/2	2 5/8	4 1/8	4 9/16	4 3/8	6 7/8	7 9/16

The lines on the opposite faces were never opposite, but were from, on one side $\frac{3}{4}$ to $1\frac{1}{2}$ inches further from the centre than on the other; in the bar shown, this distance was $\frac{3}{4}$ inch. In some of the eyes also there was an appearance of looseness about the pin-holes shown by an actual separation of the fibre for $\frac{1}{8}$ inch. The bars were tested to 20,000 pounds per square inch without set. It is nevertheless certain that the iron in the eye was not in condition to give its greatest strength. Even if we decline to recognize the existence of fibre, we cannot deny that iron is stronger in the direction in which it is rolled than in any other, and that well-worked, compact iron is stronger than that which is slightly worked.

I have been asked to describe the process of preparing the bars for the anchor chains of the East River Bridge, before they were covered up in the masonry. The bars had been painted, and when delivered had considerable rust upon them. A long shed was prepared with an overhead travelling truck (cheaply made), to which were attached two differential pully blocks for lifting the bars. Underneath, at a convenient height for the workmen, was a double line of rails on which the bars could be slid along for painting; at one end of the shed were placed, side by side, five vats. In the first was a solution of potash to remove grease and paint; in the second and fourth, water for rinsing; in the third, dilute sulphuric acid, and in the last was lime-water; the potash and lime vats were heated by steam. The strength of the solution is not very material, as it only affects the time required to produce the desired result.

Four bars were usually in each vat at once. The intent was to remove the scale entirely by the acid, but we soon found that the bars were eaten too much before it came off. Resort was then had to hammering to detach it, the object being to secure a clean metallic surface. After cleansing, the bars were left in the boiling lime-water until thoroughly heated. They were then rinsed quickly, and while hot, coated with raw linseed oil. After this had hardened thoroughly, raw linseed oil mixed with Spanish brown and the boiled oil with Spanish brown were applied. The pin-holes were then thoroughly cleaned, made smooth and rubbed with raw oil.

After the bars were put in position in the masonry, they were subjected to a heavy upward strain to bring them to bearing; they were then adjusted and wedged; next, thin grout was poured around the eyes and pins and rich concrete filled around the bars. Recent examinations at Niagara show that with our American cements, this process affords an absolute protection against rust.

THE MECHANICAL PROPERTIES OF BRONZES.

BY M. TRESCA.

Translated from "Annales du Conservatoire."

During the siege of Paris we had frequent occasion to ascertain the difference of results in experiments on the properties of bronzes; afterwards it seemed to us that it would be useful to determine more leisurely the properties of this alloy, of which the normal composition is 100 parts of copper to 11 of tin.

In the year 1872, in order to investigate the properties of bronze prepared with phosphorus, M. Morin procured two bars of bronze of the same dimensions; one cast by the old processes, the other by the phosphorus process.

The dimensions were such that the casting could be made under the best conditions. But tin spots were numerous, and a great number of bubbles appeared on some of the surfaces. We have made our experiments on the clearest portions of these bars, detached and planed so as to afford solids of exact geometric form.

In 1870 we found that the most compact and homogeneous bronzes offered the most resistance to tension.

We made out of the Bourges bronzes small test rods, similar to those used during the siege; and we should be satisfied with the figures we obtained, even were they not confirmed by other results. MM. Laveissiere, who made in 1870 more than 100 cannon, and sent specimens to the Vienna Exposition, allowed us to cut samples, so that we might test their powers of resistance. The samples were of the same dimensions as those from Bourges, and were submitted to the same test. The following is the composition, as determined by M. L'Hôte:

COMPOSITION.	BRONZE, Ordinary, of Bourges.	BRONZE, Phosphorus, of Bourges.	BRONZE, Laveissière, Mean of 3 analyses.
Copper	89.87	90.60	89.47
Tin	9.45	8.82	9.78
Zinc	0.31	0.27	0.66
Lead	0.37	0.31	0.09
Total	100.00	100.00	100.00

M. Alfred Tresca had charge of the experiments under my supervision.

That there might be no uncertainty in the results, it was necessary to vary the methods as much as possible.

The large bars of $0^m.025 \times 0^m.050$ by a length of one metre could be tested only by flexion. Two bars have been used in each experiment, so that the coefficient of elasticity, the load and the extension corresponding to the limit of elasticity have been determined for the Bourges and the phosphorus bronze. Another experiment in flexion had already been made upon the entire bars, from which the above were taken, with dimensions of $0^m.060 \times 0^m.100$ by 2^m in length. The coefficient of elasticity differed but slightly from the preceding. It is the only coefficient which can result from special experiments in which no alteration is in any way made in the material.

The experiments in traction were more varied. In each case two bars were broken with dimensions of $0^m.025 \times 0^m.025$ by 1^m in length.

The elongations were measured with the greatest care by means of cathetometers. In this way have been determined the coefficient of elasticity, the load and elongation corresponding to the limit of elasticity, and the load and elongation corresponding to rupture. All these are shown in the table of coefficients. But of the last we have not taken account in the means for a reason given further on.

Experiments have also been made upon cylinders 0.012 in diameter and 0.15 long. Two parallel scratches, distant 10 centim. from each other, were repeated with the same opening of the compass along with the increase of the loads, so that each sample showed a record of all the operations upon it. The first marks are almost coincident for small loads, but for large loads they are very distinct, and it is these that are of real value as tests.

We have expressed in definite amounts only loads and elongation of rupture.

As regards the breaking load per square metre, the experiments show that it is always larger for the small cylindric sample than for the large square one. We have taken the mean of these two values.

The elongation corresponding to rupture has been referred to the metre in length, and the actual elongations have been increased tenfold for all measures deduced from the primitive length of $0^m.10$. This has led to results requiring explanation; and we shall avail ourselves of this opportunity to show how illogical is this method of evaluating great elongations. As soon as the limit of elasticity is passed, they result at once from proportional elongation, distributed with more or less regularity all along the piece, and form a purely local elongation corresponding to the sections most extended. Increasing this tenfold gives a false notion of the phenomena.

It would be better that the result should be obtained from a test-piece having the same dimensions in diameter and length.

The breaking load per square metre and the corresponding elongation are manifestly affected by the form and size of the transverse section.

As we were not able to take a mean of the elongations measured for a length of one metre and a length of $0^m.10$, we shall refer only to the last, which alone are capable of comparison with the proof coefficients in use for materials employed in ship or railway construction.

The following tables were calculated from graphic constructions:

	FORMS AND DIMENSIONS.	COEFFICIENT OF ELASTICITY. E.	LOAD AT LIMIT OF ELASTICITY. R_e.	CORRESPONDING ELONGATION. i_e.	BREAKING LOAD. R_r.	CORRESPONDING ELONGATION. i_r.
		ORDINARY BRONZE OF BOURGES, B.				
Flexion	$0.050\times0.025\times1.00$	8.100×10^9 1.14	9.677×10^6 1.00	1.19×10^{-3} 1.02	»	»
Flexion	$0.060\times0.100\times2.00$	(8.120×10^9) 1.15	»	»	»	»
Traction............	$0.025\times0.025\times1.00$	7.077×10^9 1.00	8.244×10^6 1.17	1.17×10^{-3} 1.00	16.620×10^6 1.00	(7.20×10^{-3})
Traction............	$\pi\times0.006^2\times0.15$	»	(7.080)	»	16.810×10^6 1.01	36.50×10^{-3}
	Means....	7.589	8.961	1.18×10^{-3}	16.715×10^6	36.50×10^{-3}
		PHOSPHORUS BRONZE (BOURGES), P.				
Flexion	$0.050\times0.025\times1.00$	9.331×10^9 1.30	10.368×10^6 1.22	1.25×10^{-3} 1.05	»	»
Flexion	$0.060\times0.100\times2.00$	(8.454) 1.18	»	»	»	»
Traction............	$0.025\times0.025\times1.00$	7.169×10^9 1.00	8.480×10^6 1.00	1.19×10^{-3} 1.00	18.924×10^6 1.00	(4.61×10^{-3})
Traction............	$\pi\times0.006^2\times0.15$	»	(8.855) 1.04	»	24.730 1.37	47.00×10^{-3}
	Means....	8.250	8.667	1.22×10^{-3}	21.827×10^6	47.00×10^{-3}
		BRONZE FROM WORKS OF MM. LAVEISSIERE, L.				
Flexion	$0.050\times0.025\times1.00$	10.025×10^9 1.24	11.630×10^6 1.08	1.18×10^{-3} 0.89	»	»
Traction............	$0.025\times0.025\times1.00$	»	10.790×10^6 1.00	1.33×10^{-3}	22.450×10^6 1.00	(6.26×10^{-3})
Traction............	$\pi\times0.006^2\times0.15$	8.098×10^9 1.00	(14.160)	» 1.00	30.090×10^6 1.34	177.00×10^{-3}
	Means....	$9,061\times10^9$	11.210×10^6	1.25×10^{-3}	26.270	177.00×10^{-3}

Further explanations are necessary in order to better characterize the different properties. The experiments in flexion were not continued long enough to determine the modifications of the surface of the metal. It was, however, observed that there was a slight enlargement of the fissures upon the samples B.

The large bars showed in different degrees a diminution of transverse dimensions in the section of rupture, especially between the middle points of opposite sides, where there was a sensible concavity in the parts most deformed. It follows that the total strain is not uniformly distributed in the section, and these inequalities evidently indicate others in the transverse direction. The distribution of these transversal strains is probably not the same for all forms of section, and therefore does not cause the same displacements.

The bars B were fissured transversely at many points, especially upon one of the edges of the prism, which presented an appearance of serration; the surfaces were warped; while the bars P are less deformed. The bars L show a more distinct nippling, with very slight fissures at the angles; the section of rupture is reduced to 0.95 of the primitive surface.

The fractures have very different aspects:

B, metallic lustre; broken surface; many grains of tin.

P, earthy look; granulated surface; great uniformity.

L, metallic lustre; granulated surface; strained zone, paler than the rest of the section.

In the case of the cylindric bars the variety of effects was still more characteristic.

The ordinary Bourges bronze broke without great elongation; the fracture was marbled with yellow and white, and there were at intervals small transverse fissures.

The phosphorus bronze had the same external appearance. There was no rupture of the wall; its transversal fracture had no metallic lustre. It was quite uniform in its dull and earthy look; but there was in one of the samples a small spherical cavity filled with another compound, the presence of which undoubtedly facilitated the rupture.

The Laveissière bronze had a more metallic and homogeneous fracture. It was particularly distinguished by the condition of its cylindric wall, which was bossed and nippled all along in a curious way; probably indicating great malleability. The circular section became at some points almost polygonal.

On one of the samples were several transverse rents, hardly perceptible, resembling somewhat those occurring in the bronze of Bourges.

We have collected in the following table all the mean results of experiments, giving the values of the resistances of elasticity and rupture, T_e and T_r, in kilogrammetres, of the work at the limit. The values i_{16} and T_{16} of elongation and of work corresponding to the load of $16.745^k \times 10$, sufficing to break the ordinary Bourges bronze, are united. In the same table appear Tredgold's coefficients from Poncelet, and the ratios of coefficients. Upon the relative values of T_e and T_r depend the most essential and characteristic differences:

	BRONZE of Bourges.	BRONZE phosphorus.	BRONZE Laveissière.	Poncelet's Figures.	RATIOS.		
					Bronze of Bourges	Bronze phosphorus	Bronze Laveissière
E...	$7^k,589 \times 10^9$	8.250	9.061	7.00	1.00	1.09	1.20
R_e...	$8^k,961 \times 10^6$	8.667	11.210	7.30	1.00	0.99	1.25
i_e....	$1^m,182 \times 10^{-3}$	1.222	1.125	1.0	1.00	1.04	0.96
T_e...	$5^{km},290 \times 10^3$	5.595	6.306	3.80	1.00	1.06	1.19
R_r...	$16^k,715 \times 10^6$	21.827	26.270		1.00	1.31	1.57
i_r....	$36^m,5 \times 10^{-3}$	47.00	177.00		1.00	1.29	4.85
i_{16}...	$3^m,65 \times 10^{-2}$	1.02	0.68		1.00	0.28	0.15
T_{16}...	$129^{km},2 \times 10^3$	51.10	7.20		1.00	0.39	0.06
T_r...	$129^{km},2 \times 10^3$	254.40	962.40		1.00	1.97	7.45

At the limit of elasticity the elongations vary little for the different bronzes, and the corresponding work is affected only by the slightly greater value of the corresponding resistance R_e. This work is estimated by taking the integral of the products of the loads by the elongations. During the entire period of elasticity, while the elongations are proportional to the loads, these quantities of work are easily estimated. Beyond this the work must be found by a quadrature of the curve, corresponding to the experimental results.

When the metal is very homogeneous, the rods elongate under loads much greater than those corresponding to the limit of elasticity; so that the work of rupture for the best bronzes is relatively large.

En resumé: 1° The coefficients of elasticity E for the bronzes B, P, and L are proportional to 1.00, 1.09, 1.20. Hence the coefficient rises one-fifth in passing from the weaker to the stronger bronze.

2° The bronzes B and P have the same limit of elasticity. That of the metal L exceeds this value by about one-fourth.

3° The elongations corresponding to this limit are proportional to 1.00, 1.04, 0.96; *i. e.*, the elongation corresponding to the limit of elasticity is almost the same.

4° The work necessary to bring them to this limit varies from 1.00 to 1.06 and 1.19; the same ratios as for elasticity. From these points of view the phosphorus bronze is better than the ordinary; the Laveissière bronze is decidedly superior to the others.

5° This is still more obvious in regard to rupture, for the coefficients are:

	R_r	i_r	T_r
B	1.00	1.00	1.00
P	1.31	1.29	1.97
L	1.57	4.85	7.45

The superiority of L is due to its great homogeneity.

6° The two last values, i_{16} and T_{16}, are in inverse order; since for each charge of 16 kilogrammetres per square millimetre, which suffices to rupture ordinary bronze, the others are not even brought to their period of striction; the deformations being very slight.

In the publication of these results, it is not our object to advocate any mode of fabrication; but we confine ourselves to a statement of the following conclusions:

Bronze in general is not sufficiently homogeneous to warrant any one mode of experimentation alone, in the determination of its properties.

In experiments it is best to operate on bars of dimensions equal in length and diameter, and to estimate breaking elongations only by direct experiment, without reduction to the metre; since the deformations cannot be assumed to follow any law of direct proportion.

Finally there are commercial bronzes more homogeneous, resistant, and elastic than those made by the government; for they suffer less deformation under a load and obtain a quintuple elongation before rupture; and seven times as much work is required to break them. We infer that industries are perfected under the stimulus of personal responsibility and interest; and it is a matter of congratulation that the Direction of Artillery have decided to study in the foundries the best processes of fabrication.

The first annual meeting of the American Metrological Society was held December 29, President F. A. P. Barnard, LL.D., in the chair. Resolutions were passed approving the plan to secure a general adoption of the metric measures and weights in different professions, after July 4, 1876. Also that the Society recommend the putting up of a standard yard and metre in the various State capitals, under the standard to be made by the Bureau of Weights and Measures of the United States. The following officers were elected for the ensuing year: President, F. A. P. Barnard, LL.D.; Vice-President, the Hon. John A. Kasson; Recording Secretary, Prof. C. G. Rockwood; Corresponding Secretary, S. D. Tillman, LL.D.; Treasurer, Prof. R. W. Raymond.

ON THE GASES MET WITH IN COAL MINES, AND THE GENERAL PRINCIPLES OF VENTILATION.

By J. J. ATKINSON.*

The following remarks were written in the hope that some or other of them might prove of service in conveying to the merely practical miner a general knowledge of the laws and principles of ventilation, as applied to mines, and of the nature and properties, chemical and physical, of our atmosphere, as well as of those of some of the gases most frequently encountered in coal mines. They were not intended to have been communicated to this or any similar institution, or they would, in all probability, not only have been put into somewhat different language, but would also have placed some of the matters to which they refer in a more purely scientific point of view. But, after all, such an alteration would, perhaps, have rendered them less useful than it is hoped they may prove to the particular class of persons for whom they were written, such as underviewers, overmen, deputy-overmen, and even workmen who may wish to fit themselves for assuming any of these offices; and, at the request of my colleague, your present President, I venture to submit them to your notice.

A variety of gases is given off by the coal and other minerals met with in coal mines; a further supply of gases arises from the breathing of men and animals, and from the burning of candles and lamps, as well as from the explosion of the powder used for blasting the coal and stone in the mines. The whole of these gases are capable of causing the death of men and animals breathing them in their pure and undiluted state, and some of them require to be mixed with many times their own volume of air before the mixture they form with it can be breathed, for any great length of time, with safety.

Some of the gases given off in coal mines, when mixed with certain proportions of air, form violently explosive mixtures. Such a mixture of air and gas, on being ignited by a naked candle or other flame, suddenly explodes and becomes one mass of living flame, scorching and burning everything that may happen to be in contact with it. Such an explosion, in general, also creates a complete hurricane, or tornado, of immense force and violence, tearing and driving all before it —knocking down the masonry erected for the guidance of the ventilation, as well as the props and timber erected to support the roof of the mine, which falls in great masses, causing bodily injury or death to those it may fall upon, and often enclosing and imprisoning those who, being unhurt by its fall, are left stunned by the concussion, more or less scorched by the flames, and, without lights, shut up to breathe the deleterious atmosphere produced by the explosion. The flames of such an explosion being extinguished, and its violence exhausted, there remains an atmosphere so hot, and so charged with noxious gases and steam, as to cause the death of all who are left alive to inhale or breathe it. This resulting atmosphere is generally termed *after-damp.*

The grand object of the ventilation of mines is to cause such a current of air constantly to circulate through them as shall, by mixing with and diluting the gases, render them harmless, and, in that state, carry them off as quickly as they are produced in the mines. It is here proposed, in the first instance, to remark upon the chemical composition of the air we breathe; then upon that of a few of the most important gases met with in coal mines, and afterwards to notice some of the leading principles of ventilation, by taking advantage of which we get rid of the gases as fast as they are given off in mines.

ATMOSPHERIC AIR.

Air is, almost entirely, a mixture of two gases, oxygen and nitrogen; carbonic acid is also present in limited but variable proportions, forming on an average about 1 part to 2,500 parts of our atmosphere. Besides *oxygen*, *nitrogen*, and a trace of *carbonic acid gas* in the atmosphere, there is always more or less of watery vapor diffused through the gases

*An Essay read before the Manchester Geological Society, by J. J. Atkinson, Government Inspector of Mines.

of which it is composed; but this vapor is variable in amount, is not considered as forming a constituent part of the atmosphere, and is therefore not embraced in statements as to the chemical composition of air; yet its effects are of the highest importance, both in the general economy of nature, and also in considerations relative to the ventilation of mines. Dry air is chemically composed of

	By Weight.	*By Volume.*
Nitrogen Gas......	77 per cent......	79 per cent.
Oxygen Gas.......	23 "	21 "
	100	100

A cubic foot of air at the temperature of melting ice (32°), and under pressure of 14.7 lbs. per square inch, or 2,116.8 lbs. per square foot, weighs 0.080728 lbs.; so that under the same conditions 1,000 cubic feet weigh 80.728 lbs. avoirdupois.

NITROGEN GAS.

Nitrogen gas is rather lighter than air taken in equal volumes, at the same temperature, and under the same pressure. The specific gravity of air being taken as 1,000, that of nitrogeng as is only 971.37, so that the weight of 1,000 cubic feet of air being 80.728 lbs., that of 1,000 cubic feet of nitrogen is only 78.416 lbs. at the temperature (32°) of melting ice, and under the pressure of the atmosphere, taken at 14.7 lbs. per square inch, or 2,116.8 lbs. per square foot. A cubic foot of nitrogen, under the same conditions of temperature and pressure, weighs 0.0784167 lbs., and a cubic foot of air 0.080728 lbs., as before stated.

Nitrogen gas has neither color, taste, nor smell, and so far it is like air itself. It will not support life, but causes death when breathed. It will not support combustion, but extinguishes lights. This gas has very little chemical affinity or attraction for other bodies; its chemical properties are rather those of indifference than of activity; its position amongst gases, in general, being almost like that of water amongst liquids, as it serves to render their properties less active. It dilutes the oxygen of the atmosphere, which could not long be breathed without being diluted with nitrogen. Nitrogen is, however, probably the best part of manures for land; and it is a component part of nitrous oxide or laughing gas, of ammonia, and of nitric acid, or aqua-fortis, as well as of many other compounds.

OXYGEN GAS.

Oxygen gas, as has been stated, forms about 21 parts by volume, or 23 parts by weight out of every 100 parts of air, being rather more than one-fifth part. The specific gravity of air being taken as 1,000, that of oxygen gas is 1,105.63; 1,000 cubic feet of air at 32°, and under a pressure of 14.7 lbs. per square inch, weigh 80.728 lbs.; 1,000 cubic feet of oxygen gas, under the same conditions, weigh 89.255 lbs.; so that this gas is rather heavier than an equal volume of air. Oxygen gas has neither color, taste, nor smell. This gas, in a free and uncombined state, is essential to life; we must breathe it in this state or die; in its undiluted state, it is not fit to breathe beyond a very short time. In our atmosphere it is fitted to sustain life by dilution or mixture with nitrogen gas. Chemical compounds in the gaseous form may contain large proportions of oxygen and yet be unfit for respiration or breathing; to be suited for this purpose, the oxygen must be free and uncombined, and at the same time diluted.

Oxygen is the most abundant substance in nature, and constitutes, at least one-third of the solid mass of the earth—23 per cent. of air and 89 per cent. of water. Oxygen has strong affinities, and combines with all known substances except *fluorine.* It forms, with other substances, no less than 136 inorganic compounds, and it would be difficult to say how many organic ones. This gas is the great supporter of combustion. Substances that burn in air burn much more vividly in pure oxygen, showing that the oxygen in the air is the supporter of combustion. Iron wire will burn in oxygen, but not in air: and this is also the case with other metals in a finely divided state. When, by breathing, we inhale air into our lungs, a part of the oxygen it contains combines with carbon, and we exhale or breathe out, as the result, an equal quantity, by volume, of carbonic acid gas, and, consequently, liberate about $3\frac{16}{21}$ times as great a volume of free nitrogen gas.

Having glanced at the chemical constitution of the atmosphere, let us next consider that of the principal gases met with in coal mining.

CARBONIC ACID GAS.

When this gas is met with in coal mines it is often called *stythe, choke-damp, or black damp.* It is composed of oxygen and carbon. We have already considered the nature of oxygen as a component part of the atmosphere, but we must not expect to find it show the same properties when chemically combined either with carbon or any other substance whatever. Carbon, the other part of choke-damp, forms the chief ingredient in coal; and coke contains a still larger proportion of this substance: but the diamond is pure carbon, in a crystalline state. The chemical composition of carbonic acid gas is—

	By Atoms.	By Weight.	By Volume.
Oxygen......	2	... 72.73 per cent......	1
Carbon......	1	... 27.27 "	1*
	1	100.00	1 condens'd.

Now, although this gas contains nearly 3 parts out of 4, by weight, of oxygen (the life-supporting element), yet, because it is combined with another substance (carbon), the result is, in this case, a poisonous gas. It is dangerous to life to breathe air containing 8 per cent., or one-twelfth of this gas. Lights are extinguished in air containing 10 per cent., or one-tenth of it. At 32°, under a pressure of 14.7 lbs. per square inch, 1,000 cubic feet of air weigh 80.728 lbs., and 1,000 cubic feet of carbonic acid gas weigh 123.353 lbs., so that it is rather more than $1\frac{1}{2}$ times as heavy as an equal volume of air. The specific gravity of air being 1,000, that of carbonic acid gas is 1,528.01. Before being mixed with air it rests next to the "thill," or floor, of mines, owing to its great heaviness or density when compared with air. This gas, besides being given off naturally in many mines, is always found to result from the breathing of men and animals, the burning of candles and lamps, and, mixed with other gases, from the explosion of the powder used in blasting. Near the mouth of an adit or drift at Butterknowle Colliery, in the County of Durham, the writer has seen several small birds lying dead from the effects of this gas. They had come to feed upon crumbs where the workmen ate their meals, close to the mouth of this, an abandoned drift, and the gas coming out of the drift at the level of the ground had overcome them. At the same colliery, in several places where the coal has been worked away, the ground has been rent up to the surface, and it is said that birds flying across these rents or pitfalls, in some instances, are so quickly affected by the escaping gas as to drop into the holes and die there. Without disputing the fact of dead birds being found in the holes, the reason assigned as the cause of their coming there appears to be rather doubtful. The effect of the gas is not, perhaps, so instantaneous as to account for it. Unfortunately, birds are not the only sufferers from this gas, for many human beings have met their deaths through breathing it; and in many other cases injurious effects are produced on the health of workmen through the mixture of this gas, in small proportions, with the air of mines.

Limestone consists of carbonic acid and lime, and chalk is of a similar composition; these ingredients, however, being generally mixed with oxide of iron, magnesia, and other substances in less but variable proportions.

PROTO-CARBURETTED HYDROGEN GAS,

LIGHT CARBURETTED HYDROGEN GAS, OR, AS IT IS SOMETIMES CALLED, MARSH GAS.

This gas is the fire-damp of mines. It contains one atom of carbon combined with two atoms of hydrogen, or some multiple of these. Taking the atomic volumes of carbon and hydrogen to be the same, it contains one volume of carbon combined with two volumes of hydrogen—in all three volumes—but the three volumes are condensed into one volume of fire-damp. The weight of air at the temperature of melting ice (32°), and 14.7 lbs. per square inch pressure, is, for 1,000 cubic feet, 80.728 lbs.; that of 1,000 cubic feet of gas, under the same conditions, is 45.368 lbs., so that the specific gravity of this gas is 562*, that of air being 1,000, it being rather more than half as heavy as an equal volume of air under the same conditions. Owing to the fire-damp of mines being lighter than air, it lodges next the top or roof in mines, until, by diffusion, it gets quite mixed with the air. This gas would soon cause

* Bunsen assumes the hypothetical volume of carbon at one-half of that assumed here; but as he gives its density at double the value here given to it, the results are not altered.

* Professor Bunsen gives the specific gravity of marsh gas at .55314, that of air being 1.

death if breathed in a pure and undiluted state ; but, when mixed with twice its own volume of air, it may be breathed for some time without serious effects. It quickly extinguishes lamps or candles when unmixed with air. Fire-damp, or light carburetted hydrogen, contains nearly 25 per cent., by weight, of hydrogen. Hydrogen is the lightest known gas, being only one-fourteenth part of the weight of air. The hydrogen in fire-damp is, however, condensed into a smaller volume than it occupies in a free state. Light carburetted hydrogen gas is chemically composed of—

	By Atoms.	*By Weight.*	*By Volume.*
Hydrogen	... 2	... 24.6 per cent.	... 2
Carbon	... 1	... 75.4 "	... 1
	1	100 "	... 1 condens'd.

In the fire-damp of mines, however, we find a small proportion of other gases mixed with it. When 1 part of fire-damp is mixed with 30 parts of air, by volume, its presence can be detected by the appearance of the flame of a candle ; and as the quantity of fire-damp is gradually increased from 1 up to 2 parts in 30 of the air, the appearance of the flame is more and more affected by it; but even in the latter proportion the mixture will not explode. The flame of the candle is surmounted by a pale blue halo, called in mining language a " top," or " cap," which partakes more or less of a brown color, according to the quantity of *stythe*, or carbonic acid gas, that may be present along with the fire-damp. The examination of the flame, for the purpose of forming a judgment as to the quantity of fire-damp mixed with the air, in mines, is, in mining dialect, called "*trying the candle,*" or "*trying the lamp.*" When the fire-damp forms as much as 1 part out of 13 of the air, the mixture becomes explosive, so that, if ignited by an exposed flame, the whole of the mixture is converted into a mass of flame ; in this state of the mixture, however, the force of the explosion is comparatively feeble. When there is only 9 to 10 times as much air as fire-damp, the explosive force is greatest. If the proportion of gas be greater than 1 part out of 9 to 10 of air, by volume, the force of explosion gradually becomes less and less, until there is only five times* as much air as gas, when the mixture will no longer explode, but, on the contrary, will extinguish the flames of candles or lamps that may be brought into it.

The presence of carbonic acid gas, or of free nitrogen gas, in mixtures of fire-damp and air, is found to lessen their explosive force ; so that if we add to the most explosive mixture one-seventh part of its volume of carbonic acid gas, it will not explode at all. Air containing one-fourth part of fire-damp, by volume, may be breathed for some time without very serious effects being produced on the animal frame. Common coal gas, as used for lighting, contains a large proportion of light carburetted hydrogen gas—the fire-damp of mines. Besides this, however, it contains a considerable proportion of pure hydrogen, some carbonic oxide, and some olefiant gas.

When a mixture of air and fire-damp is exploded, the chemical changes that take place, and the nature of the resulting mixture, or after-damp, are as follows :

MIXTURE BEFORE EXPLOSION.

		By Atoms. No. of Atoms.		Relative Volume per Atom.		Uncombined Volume.	*By Measure.* Combined Volume.	Volume per cent.
Air.................	Oxygen.............	4	x	1	=	4	18.8	90.385
	Nitrogen	7.4	x	2	=	14.8		
Fire-damp...........	Carbon.............	1	x	2	=	2	2	9.615
	Hydrogen...........	2	x	2	=	4		
						24.8	20.8	100.000

* "Even when mixed with three or nearly four times its bulk of air it burnt quietly in the atmosphere, and extinguished a taper." "When mixed with between 5 and 6 times its volume of air it exploded feebly." "It exploded with most energy when mixed with 7 or 8 times its volume of air, and mixtures of fire-damp and air retained their explosive power when the proportions were 1 of gas to 14 of air. 1 of carbonic acid added to 7, or 1 of nitrogen added to 6 parts of explosive mixture rendered them inexplosive."—*From the Collected Works of Sir H. Davy, page* 10, *Vol. VI.*, 1840.

MIXTURE AFTER EXPLOSION.

		By Atoms.					By Measure.	
		No. of Atoms.		Relative Volume per Atom.		Uncombined Volume.	Combined Volume.	Volume per cent.
Free Nitrogen		7.4	x	2	=	14.8	14.8	71.2
Carbonic Acid Gas	Carbon	1	x	2	=	2	2	9.6
	Oxygen	2	x	1	=	2		
Steam	Hydrogen	2	x	2	=	4	4	19.2
	Oxygen	2	x	1	=	2		
						24.8	20.8	100.0

Before explosion, there may happen to be present either an excess of air or of fire-damp, beyond what is necessary to cause the explosion ; and if so, they will remain mixed with the after-damp, in an unchanged state, after the explosion has taken place. There never can, however, be such an excess of air present as to render the after-damp fit to breathe, or the explosion could not take place ; the limits are such that this is impossible. The above proportions of 1 of fire-damp to 9.4 of air form the most explosive mixture, all other proportions forming less explosive mixtures.

From the second table, we perceive that the after-damp contains between seven and eight times as much free nitrogen as carbonic acid gas, or choke-damp. It was, at one time, a popular mistake to suppose that the injurious part of the after-damp consisted only of carbonic acid gas, or choke-damp—not amongst scientific chemists, but amongst respectable mining authorities—and that, not very long ago. After-damp, it may be seen, by the second table, contains about 71 parts of free nitrogen, 9½ parts of carbonic acid gas, and at the moment of explosion, 19 parts of steam ; so that it may be said, at this stage, that after-damp contains, in round numbers, seven parts of nitrogen, one part of carbonic acid gas, and two parts of steam, out of a total of 10 parts. Directly after the explosion, a large part of the steam condenses and leaves, as a residuum, about 7½ parts of nitrogen and one part of carbonic acid gas, out of eight and one-half parts ; the whole unfit to breathe, and incapable of supporting either life or combustion. A small excess of air, or of fire-damp, might be left mixed with the after-damp of an explosion, beyond what is noticed in the tables as being chemically changed ; but in no case could the air of the after-damp contain less than twice its own volume of deleterious gases, or the explosion could not have taken place ; such a mixture, if breathed, would soon cause death. Since explosions cannot always be prevented, how important it is, then, to be prepared to mix and dilute the after-damp with fresh air, in as speedy a manner as possible, after their occurrence. If there is more fire-damp present than is chemically changed by an explosion, the force of the explosion itself is lessened, but the after-damp resulting is more deadly than if an excess of air had been present at the time of explosion.

CARBONIC OXIDE.

This gas is sometimes called white-damp, when met with in mines. Assuming, as before, that the atomic volume of carbon is twice as great as that of oxygen, its composition is as follows :

	By Atoms.	By Weight.	By Volume.
Oxygen	1	56.69	½
Carbon	1	43.31	1
	1	100	1 condensed.

Its specific gravity is 975.195, that of air being assumed at 1,000 ; so that 1,000 cubic feet of air at 32°, and under a pressure of 14.7 lbs. per square inch, weighing 80.728 lbs., an equal volume of this gas under the same conditions will weigh 79.426 lbs., and one cubic foot under the same conditions will, therefore, have a weight of .079426 lbs.

Carbonic oxide has a much more deleterious effect on the animal economy than carbonic acid ; air which contains only one per cent. of carbonic oxide almost immediately causes the death of warm-blooded animals, as has been shown by the decisive experiments of M. Felix Leblanc. Carbonic oxide is itself an inflammable gas, but does not support the combustion of other bodies. It has no taste, but has a peculiar odor. Small animals immersed in it die instantly. When inhaled, it produces giddiness and fainting fits, even when mixed with a fourth of its bulk of air. It is easily kindled, and burns with a blue flame, being transformed into carbonic acid by the process. The carbonic acid formed by combustion at the bottom of a coal, coke, or charcoal fire is sometimes converted into carbonic oxide, by being deprived of a part of its oxygen, as it passes upwards through the red-hot embers; and, on coming into contact with the air, at the top of the fire, burns there, with a blue flame, and is again converted into carbonic acid gas. This gas is, perhaps, never found in coal mines except as the result of the explosion of gunpowder, or the combustion of coal or wood. Carbonic oxide is obtainable in a state of purity by heating yellow ferro-cyanide of potassium with eight or ten times its weight of oil of vitriol. Bunsen obtained it by slightly heating a mixture of formic and sulphuric acids; and to ensure the perfect purity of the gas, he passed it through a concentrated solution of caustic potash. Such a proportion of this gas might be mixed with air as to form a mixture in which candles or lamps would burn, while life would become extinct; and it is probable that many deaths in mines have resulted from this gas, in situations where the lights have continued to burn.

It appears to be very probable that the deaths of the men and boys in the late accident at Hartley Colliery arose in a great measure from this gas given off by the furnace, after the stoppage of the air-current by the closing of the shaft; inasmuch as the lights used by the workmen engaged in clearing the shaft appeared to be rather increased in brilliancy than otherwise at the time when the worst effects were felt from the escaping gas; and the mine gave off no fire-damp and very little choke-damp.

At page 120, in the minutes of evidence taken before a Select Committee of the House of Commons, on accidents in mines, in 1835, the late George Stephenson, in reply to question 1853, gives an account of an accident at Newbottle Colliery, by which several persons lost their lives by a gas in which the lights burnt well, and which the witness supposed to have been sulphuretted hydrogen gas; but it appears to be more probable that it was a mixture of carbonic oxide, sulphurous acid, and a small quantity of carbonic acid gases, generated by the explosion of gunpowder in the drift, where it was found to prevail; because sulphuretted hydrogen gas has a particularly offensive smell, of which no mention is made in the account of the accident.

The writer is acquainted with several instances where gases have caused deaths, and with others where they have caused severe indisposition, in places where candles continued to burn brightly; in some of these cases, the gases were apparently produced by the explosion of gunpowder, and in others, by the combustion of coals; and hence it appears to be probable that carbonic oxide was a prominent ingredient in them. In an experiment by M. Leblanc, a large-sized dog was asphyxiated in an atmosphere which contained 4 per cent. of carbonic acid, and only ½ per cent. of carbonic oxide.

HYDRO-SULPHURIC ACID, OR SULPHURETTED HYDROGEN.

This gas is sometimes met with in coal mines. It is colorless, but distinguishable by its unpleasant smell, which resembles that of rotten eggs. It produces fainting fits and asphyxia, if inhaled, even when present only in very small proportions with atmospheric air. When inhaled, in its pure state, it acts as a powerful narcotic poison. It does not support combustion, but is itself inflammable, and burns when exposed to a supply of air and ignited; and, when mixed with oxygen gas, the mixture is explosive. It reddens tincture of litmus, but the reddening disappears on exposure to the air.

The composition of sulphuretted hydrogen is as follows:

	By Atoms.	*By Weight.*	*By Volume.*
Sulphur	1	94.15	1-6th
Hydrogen	1	5.85	1
	1	100	1

According to Bunsen, the specific gravity of this gas is 1,174.88; that of air being assumed at 1,000, under the same conditions as to temperature and pressure. Sulphur heated strongly and repeatedly sublimed in fire-damp freed from oxygen by phosphorus, produced a considerable enlargement of its volume, sulphuretted hydrogen was formed, and charcoal precipitated; the volume of sulphuretted hydrogen produced (ascertained by absorbing it by solution of potassa) was exactly double that of the fire-damp decomposed.

Sulphuretted hydrogen gas may be inflamed by charcoal or iron, even at a low red heat. In air it burns with a blue flame, forming water and sulphurous acid, and depositing sulphur. According to some authorities, 1-1500th part of this gas in air is instantly fatal to small birds, 1-1000th killed a middle-sized dog, and a horse died in an atmosphere that contained 1-250th part of its volume. The presence of sulphuretted hydrogen gas in the atmosphere, even in small proportions, can be detected by its action upon moist carbonate of lead, spread upon white paper, which it blackens. M. Parent Duchatelet observed that workmen breathed with impunity in an atmosphere containing 1 per cent. of sulphuretted hydrogen, and he states that he himself respired air containing as much as 3 per cent. of the gas, without experiencing any serious results. This gas is formed whenever sulphur in a very comminuted form is brought into contact with hydrogen in the act of being given off, and is probably formed, to some extent, where pyrites is undergoing decomposition in mines. When this gas is present with the air, in mines, candles will burn in the mixture, so that, if it is not detected by its odor, it may prove fatal to life before its presence is detected.

It appears to be probable that this gas is frequently formed in old unventilated workings partly filled with water. There are two instances mentioned by Mr. Nicholas Wood, in his evidence before the Committee of the House of Commons on accidents in mines, in 1853—one at Hartley Colliery, which proved fatal to one person, and another at Tyne Main Colliery, where ill-effects were felt, notwithstanding that the lights burnt well; both of which, in all likelihood, were due to the generation of this gas from the action of the water upon pyrites in old workings.

A man breathes into his lungs about one-fifth of a cubic foot of air per minute, and converts about seven per cent. (by volume) of this into carbonic acid gas, which, with about three and three-quarter times as much free nitrogen, he exhales, along with about 66⅔ per cent. of the air he breathes, in an unchanged state. The largest lamp used in mining converts less oxygen into carbonic acid gas than a workman. Both give off water vapor as well as carbonic acid gas. When coal is on fire, it gives off, in burning, carbonic acid, carbonic oxide, and sulphurous acid gases. The explosion of gunpowder gives rise to carbonic acid, nitrogen, carbonic oxide, and steam, besides carburetted and sulphuretted hydrogen in small proportions. In the ordinary course of mining, these causes give rise to so small a quantity of gas, in proportion to the air, that they hardly belong to the subject in hand, unless in reference to the state of a confined and unventilated part of a mine, where a shot has been fired, or in the more rare case, of coal being on fire in a mine.

Sir Humphrey Davy discovered that the flame of ignited gas would not pass through fine wire gauze, containing 28 holes for each inch in length, or 784 holes per square inch, unless the gas is moved with great velocity against the gauze, or the gauze against the gas; and by enclosing the flame of an oil lamp in a cage made of this gauze, we are able to carry a light into an explosive mixture of air and gas without setting the gas on fire on the outside of the gauze; by this means an explosion is avoided. If we find ourselves with a safety-lamp in an explosive atmosphere, we should only try to put out the flame by carefully drawing down the wick, and by no means try to blow it out, or we might blow the flame through the gauze, and cause an explosion. An explosion might result from drawing the flame of the lamp through the gauze by means of a tobacco pipe; yet workmen are not unfrequently detected in this very daring and dangerous practice in mines. Outside-feeding, or oil-tubes, used to be attached to safety-lamps, but these are dangerous, as the flame might pass down the wick tube, and up the oil tube, and so fire the gas on the outside of the lamp, if the oil-plug was out or fitted badly, and the wick was small compared with the tube; but feeding tubes are not used now, at least in many districts. There are several sorts of safety-lamps now more or less used, which give more light than the Davy-lamp; glass being used in lieu of gauze opposite the flame. Glass is brittle, and liable to crack from unequal expansion, and many persons do not think glass lamps so safe as the Davy, in consequence. The late George Stephenson contrived a safety-lamp, having both glass and gauze around the flame, known as the Geordy, or Stephenson lamp. The Davy lamp is perhaps the best known lamp for detecting the presence of a small mixture of fire-damp in the air of a mine.

Now since fire-damp, choke-damp, and other gases are met with, in more or less abundance, in all coal-mines, it becomes an important question as to how the bad and often fatal effects they are likely to produce, if not properly dealt with, may best be avoided. To this end it has sometimes been proposed to get them to combine chemically with some substance to be presented to them as they are given off; and only a short time ago a Mr. Wall had a proposition of this kind before the public. So far, however, the best mode of dealing with them appears to be to dilute them with very large quantities of fresh air, and to sweep them out of the mine by an energetic ventilation, as fast as they are given off or generated. After all, however, the natural laws and principles, operating in the production of ventilation in mines, have been less generally studied in England than on the Continent; and from this cause many mistakes have been made in the practice of ventilation in this country. New arrangements for the ventilation of mines have sometimes been made at great cost, and have not been found to answer when completed. In a few cases, lives have been lost from this cause; in others, an inferior arrangement and ventilation have been produced, where, by the application of these natural principles, a superior one might have been obtained at the same or even at a smaller cost. Many, if not all the members of this Society, are familiar with the details of the general practice of ventilation as pursued in this country. Instead, therefore, of considering this part of the subject, it is here proposed rather to direct attention to the natural laws and principles affecting the ventilation of mines.

NATURAL LAWS AND PRINCIPLES AFFECTING THE VENTILATION OF MINES.

As an introduction to the general laws and principles affecting the ventilation of mines, let us notice some of the general physical properties of air and gases. The world on the surface of which we live is a large globe, about 8,000 miles in diameter, and 25,000 miles in circumference. This great globe is surrounded by, and enclosed in, an atmosphere of air many miles in depth; so that the surface of the earth, where we live, is the bottom of a deep sea, or ocean of air. Air is composed of the two gases, oxygen and nitrogen, in the proportions that have been named. Air and all gases have the following physical properties: They are *impenetrable.* If any space be filled with air, no other material body can occupy the same space without first displacing the air, because no two material bodies can be in the same place at the same time. Two gases, or a gas and a vapor, may fill the same space (in a certain sense), by being mixed with each other, in the same manner that a sponge will hold water, but each gas or vapor must leave spaces vacant for the other to occupy or fill. Air and gases are possessed of the property called *inertia.* With respect to motion and rest, air, gases, and indeed all kinds of matter, are said to be *inert*, so that they will remain either at rest or in the same state of motion, until acted upon by some force or resistance. This property merely implies what may be termed a negative quality, of such a character as to have the effect of causing matter not to change its state, whether of motion or of rest, without some force or resistance being applied to it to cause it to do so. Owing to the property of *inertia*, a body will remain either at rest or in the same state of motion, both as to speed and direction, in spite of any forces or pressures that may be acting upon it, provided they are equal and opposite forces, so as to counterbalance each other. This is the state of the atmosphere in a calm: there is always a pressure in every direction, up, down, sideways, diagonally, and in fact in every direction, in the air of the atmosphere. This pressure arises from the mere weight of the superincumbent air, and amounts, generally, to nearly one ton on each square foot, or 14 lbs. and upwards per square inch. If the pressure is lessened on one side, the ordinary pressure upon the opposite side drives the air towards the side where the pressure is reduced, and gives rise to a wind. If the pressure is increased on any side, the air is driven away to the opposite side, against the ordinary pressure. Air in motion cannot properly be said to have any more pressure or tension than the still air through which it moves. What would otherwise be extra pressure is really converted into motion in the air. Any excess of pressure really existing is simply that due to the friction which the air encounters in moving. This is a fact not always understood, and not always acknowledged, even in works pretending to treat the subject upon scientific principles. Force may be converted into mere motion without at all increasing the tension or spring of the air to which it applied; if it does increase the pressure on the air, it is only to the extent of the resistance encountered. Air in motion is called "wind;" and owing to its *inertia* it will only lessen its speed by meeting with fractional resistances, or by giving out its force to obstructions, such as the surface of the earth, houses, trees, wind-mills, and other objects; and in every case where power is taken out of the wind, it is done at the expense of lessening its velocity. If, for instance, we should make the wind passing through a mine drive a mill, we would thereby lessen the force and quantity of wind circulating in the mine, in a given time, if the pressure causing ventilation remained constant. Railway trains, at high speed, even in a calm, meet with a large share of their resistance from the air—the trains lose force, and the air gains what they lose. Owing to the *inertia* of the air, birds meet with such a resisting medium in it as to give them a fulcrum, or resting place, for their wings, and enable them to fly. This property of *inertia* belongs alike to all material bodies, and may, in general terms, be called an *unwillingness to move, when at rest, or to change their speed or direction of motion when they are moving*, without a force or resistance being applied to cause them to do so. Air is *compressible*. Air is squeezed and contracted into less and less bulk as we increase the pressure upon it. If we double the pressure (without changing the temperature), the same air only fills one-half of the space; if we treble the pressure, it only fills one-third of the space; and if we apply four times the pressure, it only fills one-fourth of the space, and so on, provided that the heat or temperature of the air remains the same. This is called the law of Mariotte, or Boyle. The air at the surface of the earth is generally pressed by the whole of the air above it, to an extent measured by 29.922 inches of mercury (reckoned at the density due to melting ice, 93°), as shown by our common barometers; a pressure equal to 2,116.4 lbs. per square foot. To give this pressure we should require the air of the atmosphere to be 26,216 feet high, if it was all as heavy as the air at the earth's surface. The fact is, however, that the air, as we go up, is pressed by less and less air above it; and owing to its elasticity, or spring, becomes lighter and lighter, so that instead of 26,216 feet, or nearly five miles high, the atmosphere is immensely higher. It gets so much thinner, rarer, or lighter, that at—

3½ miles above the surface of the earth it is—			2	times rarer
7	"	"	4	"
14	"	"	16	"
21	"	"	64	"
28	"	"	256	"
35	"	"	1,024	"

And so on. If we carry a barometer up a hill, we have less and less air above us, and its pressure will, therefore, support less and less height of column of mercury, and hence the barometer falls. If we take it down into a mine, we get a longer column of air above us, and it supports a longer column of mercury, so that the barometer rises. In ordinary states of the weather mercury is about 10,800 times as heavy as the same volume of air near the surface of the earth, and hence about 900 feet, or 150 fathoms, of ascent or descent, makes a change of one inch of mercury in the height of the barometer. This fact has been applied to measure the height of mountains by means of barometers, and it has sometimes been employed to estimate the friction of air in shafts. The difference between the height of the barometer at the top and the bottom of a pit 150 fathoms, or 300 yards in depth, is about one inch of mercury.

Air is *elastic;* it is a perfect spring, so that whatever force compresses it is an exact measure of the force it will spring out with, if we take away the compressing force. The air, at the surface of the earth, is pressed at about 14.7 lbs. per square inch, and if we take half this pressure off, it will swell out to twice its previous bulk; if we take away three-fourths of this pressure, and only leave one-fourth, the same air will swell out and fill four times the space it previously occupied, and so on. Whatever force or power is expended in compressing air into less bounds, will be given out as force or power by the same air, in swelling out to its former volume, when we take away the pressure so applied.

Air has *weight*, like all other material bodies. The weight of a vessel filled with air is greater than its weight when the air is pumped out of the vessel. A tall column of air, one foot square, and of the full height of the atmosphere, weighs nearly one ton. Another column of the same height, and one inch square, weighs rather more than fourteen pounds. The weight of the atmosphere enables it to support a column of water nearly 34 feet high, or one of mercury nearly thirty inches high; and this pressure acts equally in all directions—up, down, sideways, and in fact, in every direction. The body of a man of average size is pressed by nearly thirteen tons weight from this cause.

The direction, speed, and force of the wind depend upon the amount of the *difference* of pressure that gives rise to it, and, in general, has little or no connection with the *gross amount* of the pressure acting in the direction of the wind; because a large share of that pressure is counterbalanced by an equal pressure, acting in the opposite direction.

In the open air the velocity of the wind is the same as the velocity that a body would acquire by falling from the top to the bottom of such a column of air of equal density as, by its weight, would produce the same pressure as that which gives rise to the wind. For instance, if the state of the air, as to the temperature and pressure, is such that there is a pressure of 2,000 lbs. (which is nearly a ton) on each square foot, in one direction; and only 1,999 lbs. per foot, or one pound per foot less, in the opposite direction, when thirteen cubic feet of air weigh one pound, then the difference of pressure giving rise to the wind is equal to one pound per square foot; and a column of air, one foot in area and thirteen feet high, would weigh one pound. But a body falling through a height of thirteen feet, under the force of gravity, would acquire a velocity of 8.02 times the square root of 13, or 28.9 feet per second; and this is, therefore, the velocity of a wind in the open air, due to a *pressure*, or rather, to a *difference of pressure* of one pound per square foot, when the total pressure of the atmosphere is nearly 2,000 lbs. per square foot, and thirteen cubic feet of air weigh one pound. If we wish to find the velocity of such a wind in the open air as is due to a known difference of pressure on each square foot, we have, first, to find how many cubic feet of the air is equal in weight to the difference of pressure on a square foot, which gives rise to the wind; and eight times the square root of this number is equal to the velocity of the wind, in feet per second. In like manner, if we would find the pressure giving rise to a wind, when we know its velocity, we must square the velocity in feet per second, and divide the result by sixty-four and one-third, and the quotient will be the height in feet of an air column giving rise to the wind; this height being divided by the number of cubic feet of air weighing one pound, will give the difference of pressure in pounds per square foot, giving rise to the velocity. This rule is merely the reverse of the former one. A difference of pressure of only one pound to the square foot, under the conditions before stated, gives rise to a wind in the open air, having a velocity of 28.8 feet per second, or more than nineteen miles per hour, which is nearly equal to the highest velocity of the air in the upcast shafts of coal mines.

In practice, in the ventilation of mines, it is found to be necessary to employ a very much higher pressure than one pound to the square foot, in order to give rise to this velocity; it is, indeed, in many instances, necessary to employ from ten to twenty pounds per square foot to do so, and this pressure is equal to the weight of an air column 130 to 260 feet high, instead of only thirteen feet high as in the open air. It has been a very common mistake to consider that this difference shows a discrepancy between theory and practice; it shows no such thing. The true theory of any subject embraces in its grasp all the causes that operate, and can never fail to agree with practice—if it is really the true and complete theory. Theory, indeed, is a collection of general principles, gleaned or generalized from observation of the result of practical trials or experiments; and it is either a false or an incomplete theory that does not embrace the whole of the general principles involved in any phenomenon we may observe. It would be true, and therefore much more becoming, in such cases, to say that we do not understand the true theory, because the hypothesis or supposition we have adopted does not agree with what we notice to occur in practice; and this ought to set us to work to try to find out what is the true theory of the matter; because practice, when not guided by general principles, is mere guess-work, or empiricism, so far as regards every case excepting only that in which the observation itself is made.

The reason of from ten to twenty times the amount of force or pressure that is required to generate any velocity in the open atmosphere, often being required to give rise to the same velocity in the air in mines, arises from the friction that air meets with, by rubbing against the sides of the air-ways, in passing through mines. Every square foot of surface exposed to the air travelling along the galleries of a mine is pressed by the air to the extent of about a ton of force or pressure, and it is, therefore, no wonder that extra pressure is required to overcome the friction arising from this immense pressure. If, for instance, we find that the last or final velocity of air escaping from a mine, by an upcast shaft, is such as to require a pressure of one pound per foot, or thirteen feet of air column to give rise to it, on the supposition that there were no friction; and if, at the same time, we find that the actual pressure employed is ten times as much, or ten pounds per square foot, we learn from this, that nine pounds out of the ten pounds per foot are required to overcome the friction of the air in rubbing against the sides of the air-ways; the other one pound per foot, or one-tenth of the whole pressure only, being required to give rise to the velocity; and this is no uncommon case in the practice of the ventilation of coal mines. Friction, then, arising from the air rubbing against the top, bottom, and sides of the air-ways in mines, is really the greatest obstacle to be overcome by the ventilating pressure or power; the force required to put the air into motion, apart from friction, being very small in comparison, at least in a large majority of cases, particularly in coal mines, which generally require a much more energetic ventilation than is necessary for the salubrity of metallic mines.

To show the comparative amounts of pressure expended upon creating velocity in the air, and upon overcoming the fractional resistance it meets with in mines, respectively, the following cases are cited, the pressures due to velocities being those due to the final velocities at the tops of the upcast shafts.

	Pressure in Air Column due to Velocity	*Pressure in Air Column due to Friction*	*Total Pressure Employed*	*Proportion due to Velocity and Friction respectively*
	Feet.	Feet.	Feet.	Feet.
Hetton Colliery, 1st. case...	10·43	179·8	190·31	1 : 18
Do. Do. 2d case....	12·37	212·63	225·00	1 : 17
Haswell Colliery...........	13.84	140·66	154·50	1 : 10
Tyne Main Do.	25.70	177·50	203·20	1 : 7

From this it will be seen, that out of a total pressure of nineteen, at Hetton Colliery, no less than eighteen were employed on friction, and only one upon the velocity of the air.

At Haswell Colliery, ten parts out of eleven of the ventilating pressure were spent upon the friction of the air; and only one part out of eleven upon creating its final velocity at the top of the upcast shaft.

At Tyne Main Colliery, seven parts out of eight of the ventilating pressure were spent upon friction; and only one part in eight upon the velocity of the air at the top of the upcast shaft.

From these examples it will be perceived that the amount of ventilation in mines, and, therefore, the safety, health, and comfort of the workmen employed in them, depend almost entirely upon the amount of friction that the air meets with, under any mode of ventilation we may employ; and hence, the great importance of understanding the general laws and principles upon which the friction of air in mines depends, so that we may know how to reduce such friction to its lowest possible amount, and by this means obtain the greatest quantity of air, from any ventilating power we may employ.

TUBULAR FLOATING DOCKS.

From "Naval Science."

It is quite unnecessary to insist at the present day on the general usefulness and merits of floating docks. The fact that they can be employed in deep water, and in situations where from the nature of the ground it would be impossible to cut docks on the ordinary system, and that too, independently of the height of the tide, is so manifest an advantage that it cannot be questioned that at a time when increased dock accommodation is urgently required their principle will be largely employed. The comparative cheapness of their construction also tells powerfully in their favor. To this must be added the consideration that floating docks are capable of being moved from place to place, so that if the demand for their use be diminished at one port, they can readily, and at small expense, be moved to another where the demand is greater; while from their comparative cheapness they can at all times be more profitably employed than fixed stone docks which have been built at a large outlay. The story of the great Bermuda dock built for the Government by Mr. Campbell, and safely towed across the Atlantic without accident or unusual difficulty, must be fresh in the memory of all who take an interest in shipping, and affords a memorable example of the truth of our observations. Floating docks of the ordinary type consist, as is well known, of parallel or nearly parallel walls terminating in a flat bottom, the space between being divided into a large number of water-tight compartments, into and out of which water may be pumped by means which need no description, and so may be raised or lowered at pleasure; so that vessels of various sizes may be received on to the dock, and then raised by pumping the water out until the workmen can obtain access to the whole of the hull, and perform the requisite repairs, and can then be lowered by admitting the water until the vessel can be floated off.

Messrs. Clark and Standfield's Patent Tubular Dock is of a totally different construction, and is worked in a different manner. Both the bottom and the vertical sides of their dock consist of a number of circular wrought-iron tubes similar to egg-ended steam-boilers. The bottom of the dock is formed of about eight circular tubes which run the whole length of the vessel and extend some feet beyond its ends. These tubes are stiffened inside by angle irons every two or three feet, and are securely braced together by transverse beams of T and angle iron above and below, which are so united by the tubes themselves and by gusset-plates as to form transverse girders of ample strength to support the platform, having sufficient buoyancy to support both the vertical sides of the dock and the vessel itself.

The sides of the dock are also formed of similar tubes which are fixed vertically. Each side is formed of from twelve to twenty-four of these vertical tubes, which are inserted upon the two outer longitudinal tubes, and attached by flanges like the dome of a steam boiler; the vertical tubes are braced together and connected by a lattice-work platform at the top running the whole length of the dock, forming a spacious gangway for the workmen. The longitudinal tubes are continuous throughout, and by means of the side tubes and braces they are so connected with the iron platform at the top as to convert the whole dock into a beam or girder of great depth and of immense rigidity. The centre longitudinal tubes are considerably larger than the side tubes, so that the general plan of the dock resembles somewhat that of an ordinary vessel. The two outer tubes are of larger diameter than the others, so as to give extra stability of flotation, and to afford convenient attachment for the side tubes.

The tubes are divided within into a great number of water-tight compartments or chambers connected together by pipes, and the raising and submersion of the dock is effected by means of compressed air. The base of the dock is divided into about sixty air-tight compartments, separated by egg-ended bulkheads, and the vertical sides form about forty additional chambers, and the whole of these last are hermetically sealed, so that the dock cannot under any circumstances sink. A certain number of the bottom chambers are so hermetically sealed; but the remainder are provided with valves at bottom which can be opened or closed at pleasure, and with wrought-iron pipes which are grouped together, and are all brought to a valve-house on the top platform of the dock, and are placed under the control of the valve engineer. When it is desired to sink the dock the bottom valves are all opened, and the air allowed to escape at the valve-house until the dock settles down to its lowest level ready for the reception of a vessel. When it is desired to raise the dock, air is forced into the tubes under compression, the water is expelled through the bottom valves, which are closed as soon as the dock and its vessel are fully raised; it then remains afloat with the vessel docked upon it, without any dependence on the air-valves.

The engines are in two pairs, placed near the centre of the dock within the vertical tubes, the main from these being led into the valve-house. The whole of the water-tight compartments in the bottom are divided into four equal groups corresponding with the four corners of the dock by means of four corresponding valves in the valve-house; air is admitted into or out of these respective groups in any desired proportions, so that the dock is maintained at all times perfectly level both in raising and lowering.

This novel form of dock has, to a great extent, the combined merits of the stone graving dock, and of the ordinary hydraulic lift or pontoon dock, together with some advantages which are peculiar to itself. It has immense stability, owing to its great breadth, and to the great number of compartments into which it is divided, which prevent the tendency of the water to flow to the lower side—a tendency which may be, moreover, corrected at any time by allowing the compressed air (which is always kept stored in the vertical tubes) to act temporarily on any of the compartments. It is provided with sliding bilge blocks, similar to those used on hydraulic graving docks, which are drawn under the vessel by chains. The vertical tubes are also well provided with side frames affording facilities for side-shoring similar to those of stone graving docks, so that even loaded vessels may be readily blocked and shored up to any desired extent; this is a point of great importance in the lifting of heavy iron-clads, and, moreover, by admitting water into some compartments and expelling it from others, the lifting power can be to a great extent exerted directly under the load to be lifted. The vessel when lifted is high and dry above water, an advantage common to all floating docks, but owing to the vertical tubes in this dock being well separated from each other, there are great facilities of access to all parts of the vessel. Two large gangways of extra width, provided with cranes, are also formed at each side for the landing of heavy timbers, plates, &c. The open sides admit of the air and light circulating freely round the work, so that paint dries and hardens much more quickly than in a sunken dock. From the same cause repairs can be executed in a much more prompt and satisfactory manner than in a stone dock.

The tubular form not only possesses great structural strength, but is peculiarly suited to withstand the extreme pressures to which floating docks are necessarily subjected both externally and internally. When an ordinary dock is submerged in deep water the air compartments have to withstand an external pressure of, say, fifteen or twenty pounds on the square inch, tending to buckle the plates and open the joints; to make these compartments square and flat is as great an error as it would be to make a square steam-boiler or square iron pipes; in either case heavy and costly struts and ties are necessary to preserve the form and prevent bursting or collapsing. In the circular form, on the other hand, the material is in perfect equilibrium, and its whole tensile or compressive strength is directly exerted in withstanding the pressure. It is well known, too, that the circular form offers facilities for caulking which are not possessed by flat boiler work. The tubes are accessible all round within and without for cleaning and painting, and by an ingenious system of canting the under sides of the tubes are made accessible for cleaning and repair. From the great number of compartments into which the dock is divided it seems scarcely possible that it could be dangerously injured by shot or collision; it is stated, indeed, that if three-fourths of the compartments were punctured the structure would still float.

In exposed positions it is proposed to submerge the dock entirely whenever it appears to be endangered by a cyclone or by stress of weather. The tubular sides afford great facilities for this operation; compressed air is pumped into them at leisure and kept stored up ready for use; after the dock is submerged the opening of the valves will at any time allow it to expand and raise the dock to the surface. This use of stored-up power is also employed whenever it is desired to raise vessels rapidly—as, for example, in examining bottoms or screws; the power being stored up and ready for use, the docking of a vessel occupies but little time; by opening communication with the water in the tubes the air expands and expels the water and the vessel is immediately raised.

The dock can, of course, be used in conjunction with flat pontoons for floating vessels, as is now done with the hydraulic lift-dock, and the combined lifting power of the dock and a tubular pontoon is obviously much greater than that of either of them separately. The pontoons being perfectly water-tight are well adapted for withstanding a sea passage, and for conveying vessels over bars or shallows, after which they can be lowered into deeper water. It is proposed, in fact, to fit these pontoons with engines and screws, and their tubular form would enable them to pass through the water with little resistance.

Not the least among the advantages of the tubular form of dock is the fact that owing to the small amount of interior strutting required, and the great simplicity of its construction, it can be put together in a much less time than an ordinary dock, and with a much smaller quantity of material, and consequently at a very greatly reduced cost.

The floating dock appears to occupy an intermediate place between the old stone graving dock and the hydraulic lift-dock. Where the number of vessels to be lifted is very great, preference will probably be given to the latter; but the floating dock has advantages of its own. In the first place, its greatly reduced cost renders it suitable for many positions in which the business is sufficient to warrant the cost of a stone dock or an hydraulic lift dock. There are several cases in which floating docks of the ordinary construction are paying dividends of 20 or 30 per cent., in positions in which stone docks would be impossible, or in which their cost would entirely preclude their adoption. It is not always easy to find a suitable position for an ordinary graving dock, and even the hydraulic lift system requires water of a certain limited depth; but a floating dock can be placed anywhere where there is sufficient depth for a vessel to approach, and can be transported from place to place.

It has been stated that the tubular dock is raised and lowered by pneumatic means; there is, of course, no theoretical reason why it should not be worked by ordinary water-pumps in the usual manner. The practical objections to the system are, that either the dock must be divided into a very few water-tight compartments, in which case it is somewhat unstable, owing to the tendency of the water to flow into the lower compartments; or else if divided into a sufficient number of compartments the size and weight of the large cast-iron pipes and pumps required for exhausting the water bear a very serious proportion to those of the dock itself, and add materially to its cost.

In pumping air small wrought-iron pipes are sufficient, and the engines may be of the slightest construction and worked at the highest speed without risk of damage, while it is at the same time possible to store up a certain portion of the air in a compressed form in the vertical tubes, which form a large reservoir of power which may be accumulated at leisure and employed at any moment required. When it is desired to lift a vessel in a moving sea this stored-up power may be of great importance, for as soon as a vessel is placed in proper position in the dock it is desirable that she should be at once partially lifted so as to secure her temporarily while additional shores and bilge blocks are being fixed.

Floating docks appear likely to be applied in future to another purpose to which sufficient attention has hitherto not been drawn. We allude to their employment as building slips for the construction or lengthening of vessels. On the ordinary system it is necessary that a building-yard should be closely adjoining deep water, and that the vessel should be constructed and launched on inclined ways, a process not always devoid of risk. By building on pontoons this risk is almost entirely avoided; any shallow river or creek may be utilized, whatever its distance from deep water, and the ways may be laid on a pontoon either floating in shallow water or resting on the ground in a shallow dry dock temporarily prepared for the purpose; and when the vessel is ready for launching, the water may be admitted to the dock, the valves closed, and the vessel floated out into deep water. During the operation of submersion it is necessary that the pontoon should have vertical sides, in order to insure stability at the point of time when the vessel first begins to take the water, and before she is fully waterborne. In a large building-yard these vertical tubes might, however, with advantage be only fixed temporarily in segments, and removed and applied elsewhere while the pontoon was being used for building a second vessel. A similar arrangement might be employed for laying up gunboats and other vessels in ordinary while out of service. A shallow dry dock would contain a large number of such vessels, all parts both of the pontoons and vessels being accessible for painting, while the admission of water would enable the whole at any time to be floated out and submerged ready for use.

In fact, floating docks have not yet assumed their proper place in the naval service. Constructed often in a temporary manner of wood or iron, and from imperfect designs, they have sometimes met with indifferent success or even with disaster; but experience has shown at once both their defects and their merits, and there is no doubt they are destined in future to become one of the most important elements both in navigation and in naval construction.

VESSELS OF WAR.

By ISAAC NEWTON, C. E.

From the New York "Times."

NEVER before was the whole subject of marine warfare in such a muddle as it is now. When Louis Napoleon launched the *Gloire*, fifteen years ago, he opened a discussion which seems never likely to come to an end. The European navies had settled down to what they supposed was a sort of "hard-pan." After more than a decade of talk and experiment they had finally got the screw fairly introduced, and the batteries were generally equipped with shell guns. The destruction of the Turkish fleet at Sinope by the Russian shell-guns and time-fuses, in the early part of the Crimean war, sent a shudder through the naval circles of Europe. The alarm was as to the then existing power of naval batteries. If the small shell-guns of the Russian fleet did such swift execution, what would be likely to happen if ten-inch shells were fired into one another's vessels? One or both of the antagonists must forthwith be sent to destruction. The standard authority on naval gunnery referred with horror to the awful power of this tremendous missile. It was this fearful anticipation, as much as the launching of the *Gloire*, that gave birth to the iron-clad era. That these anticipations were entirely justifiable the fearful carnage which the shells of the *Merrimac* in a few minutes inflicted on the *Cumberland* and *Congress* is abundant proof.

It was at this time, in 1861, that the *Monitor* made its appearance. England had already begun her iron-clad navy, and had launched the *Warrior*, the *Black Prince*, the *Defense* and another. The French had built a companion to the *Gloire*. The fight between the *Monitor* and *Merrimac* changed the whole aspect of things. Foreign powers saw that wooden ships had no show against shell-guns in shot-proof vessels, and that we had been able to build within a hundred days a ship that solved the iron-clad problem, and was capable of sinking any French or English wooden ship that might come against it. The fact too was apparent that a few months would give us a fleet of just such vessels. And in a few months we had the fleet. But we have made no attempt since the war to compete in iron-clad construction with England and France or any of the European powers. We have practically ceased to place reliance on guns for the defense of our harbors. Our course now is plain. It is to attack an enemy below the water-line—abandoning all devious attempts to overcome his armored sides—and thus to neutralize whatever advantage he may have obtained by colossal expenditure on iron-clads.

The fact that attack below the water-line by subaqueous weapons is destined to utterly revolutionize naval warfare would seem to be too plain to require labored demonstration; but undoubtedly another great war will be needed to convince naval authorities of it. England, France, Germany, and Russia vie with each other to produce an iron-clad absolutely impregnable to existing artillery. England has just put the monitor *Inflexible* on the stocks. She is to have twenty-four inches of armor on her turret, and is to carry guns firing shot weighing 1,200 pounds. Russia has launched the *Peter the Great*, and Germany follows with her *Frederick the Great*. Meanwhile, the naval writers of Europe are filling newspapers, magazines, and pamphlets with discussions and controversies as to the general character and powers of iron-clads, and, strangely enough, naval officers are preparing elaborate treatises on naval tactics for the disposition of these monsters, as if they were to be handled and manœuvred as Von Moltke could an army corps on a smooth plain. Inasmuch as a few hundred pounds of nitro-glycerine, or some other of the modern explosives, fired in contact with their unarmored sides below the water, would send the strongest of these naval giants to Davy Jones's locker before even the simplest of "naval tactics" could be put into operation, we must regard the work of these industrious tacticians as thrown away.

The inability of the naval specialists to appreciate the situation, and the consequent muddle that exists throughout Europe as to models of vessels, the character of armor, the purposes to which naval vessels may be put, and the methods of naval warfare, are indications of the coming revolution. To show the extreme to which they go, we find little kingdoms like Sweden and Norway building an insignificant number of broadside iron-clads, thus feebly following in the wake of Russia and Germany. Of course, these vessels are of no use to such a power for offensive purposes, and as for defensive purposes they are worthless, and their whole construction is simply a frivolous waste of money, prompted by vanity and a foolish attempt at rivalry. It is hard for the naval minds to understand that the old ideas of naval power are fast approaching an end. A clear observer, informed as to the situation, must recognize the fact that twenty-five years from now a navy will exist only as a means of defense for the great nations. The vast sums that are spent every year in maintaining and increasing the navies of Europe on their present system may, therefore, be regarded as practically thrown away. The comparatively inexpensive submarine monster, applied to defensive uses, will neutralize all the millions that are now wasted on enormous naval constructions.

A Wooden Railroad in Michigan.—The tram road of Van Etten, Kaiser & Co., at Pinconning, Bay county, Michigan, is 11 miles long, and is thus described in a communication to the Chicago *Railroad Gazette:* There are first logs 12 to 16 feet in length laid crossways about five or six feet apart. Then gains are cut in the logs and flatted timber laid in these gains; this prevents the road from spreading. Our rails are of hard maple. Before spiking the rails down we put ties across the stringers, notching the stringer enough to let the tie down even with the top of stringer and spike the tie fast before the rail is laid on. The ties are of two inch hemlock plank from 6 to 12 inches wide; this prevents the stringer from rolling. We would recommend any one who wishes to build a road on the above system to build it as straight as possible. We have been obliged to dispense with wooden rails on the curves and lay down iron. We operate our road with locomotive power. Cost of building without rolling stock is $2,000 per mile.

THE WARNER PROCESS.

From "The Engineer."

Since Cort invented the process of puddling in 1784 the substantial improvements which have been effected in the method of converting cast iron into wrought iron have been very few. The Bessemer and Martin system revolutionized the steel trade, but nothing analogous to the Bessemer or Martin process in its effects on a great industry has been introduced in the production of wrought iron, and this notwithstanding that legions of inventors have spent time and money in attempting to solve an apparently unsolvable problem. If the rotating puddling furnace can be made a substantial commercial success, then it is more than probable that Cort's invention will be superseded after nearly a century of use. But we cannot regard any system of mechanical puddling yet produced as perfectly satisfactory; and even though this were not the case, there is reason to believe that other systems of purifying cast iron might be adopted either alone or in conjunction with a mechanical puddling furnace with advantage. We regard therefore with interest every attempt which is made to supersede or supplement the ordinary system of hand puddling, and we have at all times endeavored to put the claims of inventors in this branch of science fairly and dispassionately before the world. In this spirit we now desire to call the attention of our readers to a novel method of manipulating pig iron, which, judging from the evidence laid before us, has proved unusually successful as compared with the results obtained by other processes intended to effect the purification, wholly or in part, of cast iron. The inventor of the new process is Mr. Arthur Warner, of London, and it is the result of many hundreds of experiments, carried out under the supervision of Mr. Warner's son, a competent chemist, and at very considerable expense. The process in itself exerts no small claim on our favor in that it does not attempt too much. Mr. Warner does not profess—as too many inventors do—to produce a perfect material from an inferior pig at an impossible cost. He has addressed himself to a specific object, and we have the testimony of many practical men to prove that he does really effect what he professes. Besides this, there is about the Warner process a definite promise and foretaste of the success in that he does not work with infinitesimal quantities of "physic," and that he can give a sound chemical reason for everything that he does. The thing is so simple that it admits of being explained in a few words, but the reactions on which its success depends require a little explanation, which we shall give before going further.

It is well known that the two principal ingredients in pig iron which the operation of puddling is intended to remove are carbon and silicon. With two other impurities—sulphur and phosphorus—the puddling furnace deals with doubtful effect. What carbon is we need not stop to explain. Silicon, or silicium, as it is sometimes called, is a peculiar non-metallic element, which, in combination with oxygen, constitutes silica. It is present in cast iron in various quantities, from 5 or 6 per cent. downward: less than 3 per cent is comparatively rare. Why the presence of carbon and silicon, except in very minute quantities, should be inimical to the existence of wrought iron, is not very clearly understood. Even though it were, we should not digress to deal with the question here. The broad fact remains that the carbon and silicon must be got out of the pig before we can have wrought iron. As it is not necessary to plunge very deeply into the chemistry of the subject, it will be enough to state that certain materials exist which have the power of combining with silicon and sulphur under the influence of heat, and of producing with them a slag or cinder which is lighter than iron and is fluid at the temperature at which iron melts. One of these materials—to select the cheapest and best known—is limestone. This is used in the blast furnace, and disposes of a large proportion of the silicon and sulphur contained in the ore. But the quantity of limestone which can be used is limited because it tends to produce "scaffolding" and to "gob" the furnace. If more could be used, the resulting pig would be purer; as it is, in practice we have varying quantities of silicon in the pig, which must be subsequently removed. Now fully impressed with the importance of the part played by limestone in the blast furnace, and knowing the advantage which would be gained—and to which we shall refer presently—by getting rid of the silicon and sulphur, Mr. Warner labored to effect the removal of both by a further use of limestone. His process, therefore, it will be understood, differs from almost all other chemical processes, so called, of purifying iron, in that it leaves the carbon untouched and deals with the silicon and sulphur alone. Mr. Warner first attempted to effect the required object by placing a quantity of powdered limestone at the bottom of a deep and narrow vessel and pouring cast iron on the top. The process was a complete failure; the limestone caked together into a mass under the influence of heat and remained at the bottom. Mr. Warner overcomes this difficulty in a singularly elegant way. He mixes his powdered limestone with soda ash, and places them at the bottom of the purifier. As the soda ash becomes heated it melts down and leaves the particles of infusible limestone free. These being lighter than the cast iron, float up through the metal, and become converted into carbonic acid and calcium. The first seizes on the silicon and oxidizes it, becoming itself converted into carbonic oxide, which escapes at the surface of the metal. The sulphur is also attacked and eliminated. In practice the operation of purifying occupies about half an hour or a little more, and during all this time the metal boils violently in consequence of the partial combustion of the silicon and sulphur, and remains perfectly fluid without any extraneous heat. In this a resemblance will be traced to what takes place in the Bessemer converter, but the temperature in the Warner purifiers is so much less, that ordinary fire-bricks can be used instead of ganister as a lining. In brief, then, the Warner process consists in placing at the bottom of a wrought iron cylindrical vessel, six or eight feet deep and two in diameter inside the fire-brick lining, a given quantity of pulverized limestone and soda ash, and pouring on this from two to ten tons of melted iron either from the blast furnace or the cupola. When the process of purification which we have described is concluded the metal is tapped out into cakes or pigs. The slag is then tapped off, and the purifier is ready for another charge. In order that no doubt may remain as to the precise nature of the process, we publish Mr. Warner's specification on another page. To use the inventor's own words, "The process is carried out in the following manner: A cylindrical plate iron vessel with fire-brick lining, mounted on wheels, and capable of holding five to ten tons of iron, is run up close to the blast furnace and under a chimney to carry off the gas and flames. At the bottom of this vessel has been previously placed the required quantity of the purifying mixture. The iron is then tapped from the blast furnace and runs into the vessel upon the top of the powder. A violent action begins at once, and lasts for twenty or thirty minutes. The carbonic acid, by the oxidation of the silicon, becomes converted into carbonic oxide, and burns at the top of the chimney with an intensely brilliant flame, colored yellow by the soda. As soon as the agitation ceases the vessel is drawn away from the blast furnace and tapped into iron moulds. The silicon and sulphur, in combination with the lime, then follow as separate slags free from iron, the carbon being increased or decreased as required." The product thus obtained is a white refined iron, practically free from silicon and phosphorus. We select a single analysis by Mr. Riley from many to show the result of the operation of the process on Cleveland pig: Combined carbon, 3.218; silicon, 0.012; sulphur, 0.092; phosphorus, 1.750. The original pig iron contained over 3 per cent. of silicon.

To convert the refined metal thus obtained into wrought iron it is puddled in the ordinary way as refined iron; but it is found in practice that owing to the removal of the silicon and sulphur alone the iron will—unlike ordinary refined metal—boil freely, and become quite fluid. The duration of the puddling process is also much reduced, so much, indeed, that at the Kirkstall Forge twenty-seven heats were got out with the aid of a dandy fire in twenty-four hours, instead of twelve, the usual number. The saving of fuel thus effected is obvious, but the reduction in the quantity of fettling required is also very considerable, for reasons which will be too readily understood to need explanation here.

So far we have said nothing as to the removal of phosphorus; and as to the success of the process in this respect we shall pronounce no opinion for the present. Mr. Warner claims to remove phosphorus altogether in the subsequent process of puddling by the use of plenty of hammer slag, and he argues that phosphorus is not got out in the ordinary process of puddling only because the silicon present in the iron seizes on the oxygen in the fettling and hammer slag, and renders them so inert that they cannot touch the phosphorus. As his refined iron contains no silicon, the oxidizing agents are free to deal with phosphorus, and do deal with it accordingly. As we have said, we shall pronounce no decided opinion on this theory, but we may state that Mr. Warner has supplied us with evidence going to prove that from some cause or other very little phosphorus indeed is to be found in puddled bars of his iron.

It will be seen that the process we have just described is very similar to many others up to a certain point, but the essential difference between it and such processes as that of Henderson is that a great depth of metal is superimposed on the purifying agents, and that no extraneous heat of any kind is employed while the process is proceeding. As regards the practical results obtained by Mr. Warner, we cannot have better evidence than that supplied on oath before a Judicial Committee of the Privy Council engaged in deciding Mr. Warner's claim for an extension of one of his earlier patents. Mr. Lee, of the Gospel Oak Works, tested about 20 tons of Warner refined metal made from Cleveland pig, and stated that he found it equal to all mine Staffordshire pig, and worth twenty shillings a ton more than ordinary Cleveland iron. Mr. Barrett, of the Kirkstall Forge, having tested the iron, ordered 500 tons of it, at twenty shillings advance on Cleveland pigs, while the testimony of Mr. Hall, Mr. Whitehouse, and others is equally favorable to the process. We cite this evidence simply to prove that the favorable opinion we have expressed concerning the process, although based on the chemical theory involved, is supported by the results obtained in actual practice, as testified to by men of immense experience and sound judgment. We may state in conclusion that Mr. Warner is, we believe, now making arrangements for the erection of works on a large scale for the production of refined pig, so that the question of the commercial value of the process will soon be set at rest forever. We have no hesitation in admitting that the process appears to us to possess more promise of complete success than any other which has been brought before the world since Mr. Bessemer made steel.

TRIAL TRIPS.

From "Engineering."

Engineering is essentially an experimental science. The mathematician and physicist discover and elucidate its laws and first principles, but are able within the limits of their own sciences only to apply those laws and principles to structures existing upon paper. The varied conditions under which the actual structures have to be erected and worked, or used, are such as they cannot within those limits take into account. In their investigations they have, for instance, necessarily to assume the perfect rigidity of various joints and fastenings the nature and strength of which vary exceedingly, and in many other ways to start with assumptions or hypotheses which may or may not correctly represent the conditions which obtain in practice. It is of the very greatest importance, in order to the growth of scientific engineering, that the class of scientific investigators to whom we allude should have their hands strengthened in every possible way. They are doing for engineering what few engineers have either time or ability to do for it—investigating and elucidating the foundation principles on which it rests, and are putting the coming race of constructive engineers in a position to work with some approach to scientific reason and accuracy. It is scarcely necessary to point out that this is not an advance in abstract knowledge merely. It means, in the first place, increased safety in structures, and then economy of labor, economy of material, and, in the case of coal-consuming machines, economy of fuel. The application of scientific principles to the design of engineering work will, in fact, make it safer, more efficient and cheaper at the same time.

The great want of all those who are engaged in the investigation of engineering science at present is experimental data by which to verify conclusions arrived at inductively, and to arrive deductively at further conclusions. The class of experiments which alone can be of much use under present circumstances must be (1) upon a sufficiently large scale (2), carried on as nearly as possible under the conditions obtaining in actual practice, and (3) noted completely in all their details. The conclusions derived from mere laboratory experiments can but seldom be applied to engineering work. Experiments, for instance, with propellers 2 in. diameter, or with model vessels a few feet long, while interesting in themselves, do not supply us with data which we can with confidence apply to 16 ft. screws or ships displacing a couple of thousand tons. The scale upon which the experiments are carried on is not, however, everything. They may be on a large scale—they may even be conducted with full-sized machines or structures—and yet be of comparatively little use. This occurs when they are carried out with a view to establishing certain pre-determined results, or proving some already assumed economy. In this class come but too many of the published experiments connected with any new machine or apparatus, the working of which invariably "exceeds the most sanguine expectations of its promoters." Such experiments (when the results published have really been arrived at, and are not, to a great extent, imaginative) are for the most carried on under exceptional conditions, or for short periods, do not represent truly the results which would be obtained in ordinary working, and, therefore, cannot be "founded on" by the investigator. It is, of course, true that it is important to know the very best results that can be obtained from any piece of apparatus, as well as its average efficiency; but for this purpose it must be stated in the account of the experiment whether the conditions under which it was carried on were ordinary or special, a little fact which inventors and patentees somehow omit occasionally to mention. The statement that experiments to be of value should be *complete*, will awaken responsive echoes in all the army of investigators, who have spent hours—or perhaps even days—wading through masses of ill-arranged information in hopes of arriving at length at the one little fact which is required as a key to all the others, and without which they remain almost useless, but which, somehow, the experimentor (no doubt a "practical" man) had entirely forgotten to state.

There is probably no section of engineering science of greater national importance to this country than what may be called marine engineering, embracing the science of naval architecture, and the designing of engines and machinery for the propulsion of vessels. There is at the same time no section of engineering work in which so many experiments are made; and yet out of all these experiments very few are of real use, even to those who conduct them, and not one in a hundred is of the slightest value to the rest of the world, including the hungry little army of investigators already mentioned.

Who does not know by heart the ordinary "Trial Trip?" and what marine engineer, whose interest in his profession leads him to examine a little below the surface, has not attended trip after trip in the vain hope that he might obtain some valuable data, and again and again come away disappointed and savage? Not a few of our readers must have experienced something like this: The tug has conveyed a crowd of gentlemen (and ladies) to the vessel, the anchor is weighed, the engines begin to turn, and a second inspection of the engine-room from the skylight showing that the preliminary confusion and crowding below has somewhat lessened, you descend to see what is going on.

Here too often you find things as dirty and confused as if the voyage were finished instead of begun ; but let us suppose that it is intended to take adventurous ladies down to admire the "things like spiders," and that consequently all the machinery is tolerably clean and bright. The indicator gear is ready, although the *lead* of some of the strings is not very good ; but a moment's inspection shows that no arrangements have been made for measuring the water that is collected from the jackets. You go into the stoke-hole, and there find two or three large, and of course unweighed, heaps of coal upon the floor, and the bunker doors open ; and on looking at the steam gauge you see that the pressure is 10 lbs. or 15 lbs. lower than that at which the boilers were intended to work. For an hour or so the course down the river is much impeded by the numerous craft, but at length the water is clearer, and the order for "full speed ahead" is given. Another visit to the engine-room shows you two indicators in place, and you find that no more are forthcoming, and that the cards will be "quite near enough" taken in this way. The first diagrams are not very satisfactory—the instruments cold perhaps—and just as another set is being taken a bearing begins to heat, and with much spluttering and splashing the engine is slowed, and the diagrams remain untaken. By the time the brasses have been cooled and eased (if, indeed, the heating does not continue all day), "the mile" is being neared, and great excitement reigns in the stoke-hole, the occupants of which you find to be hard at work under the eye of the manager himself. The throttle valve is wide open, the engines in full gear, water pouring over the offending bearing, and possibly over others as well, and the lads at the indicators working for very life. It is soon over, and when you presently inquire the speed you may probably be surprised to find that the captain's and the manager's statements differ by some thirty or forty seconds, if, indeed, you are fortunate enough to get any definite statements from any one. Then come lunch and the speeches, and, as an invited guest, you feel it would be uncivil to leave the table till they are finished, but you know that the vessel has turned, and that while "The owners" or "The ladies" are being enthusiastically toasted you are running the mile in the homeward direction. At last you are once more in the engine-room, where you find that various "linked-up" cards have been taken, and that the fuel has been measured for half an hour or so by some method extemporized on the spur of the moment by some well-meaning draughtsman, and found to be at the rate of about 1.5 lbs. per indicated horse power per hour ! Disgust seizes you, and you visit the engine-room no more, but endeavor by the aid of a cigar on deck to quiet your feelings sufficiently to enable you to make the necessary commonplace compliments to your host before the tug takes you ashore again.

The sum total of the information derived from such a trial trip, and we have really given no unfair picture of trips that occur every week—almost every day—is this. A vessel of a certain length, breadth and depth, ran a knot in somewhere between five and six minutes on a fine day in a smooth river, and the engines indicated at the time so many horse power, actually or approximately. The diameter and stroke of the cylinders, and possibly the dimensions of the propeller and the boilers, constitute with this the whole of the information which any one not in some way officially connected with the vessel is able to obtain, while the engine builders will, of course, know in addition all the dimensions of the various parts, and (but sometimes only approximately) the heating and condensing surfaces. The draught of water has not been observed, or has only been noticed approximately or casually, and the immersion of the screw is guessed at. It never enters into any one's head to find out the displacement or the immersed midship section, still less to calculate either the actual or the "augmented" immersed surface. As regards knowledge of the laws, or even the facts, of propulsion, the trial trip is of scarcely the slightest use to the builders of the ship or the makers of the machinery, and of none whatever to any one else.

And yet with very little additional expense or trouble the trial trips, which are so constantly taking place, might be made to yield information which would be of much direct practical value to the engineer, and would also in the hands of scientific men add immensely to our knowledge of all the laws relating to the resistance of vessels. A trial trip might be rendered a complete scientific experiment upon the largest scale, and under all, or nearly all, the conditions of actual practice—just the kind of experiment, in fact, which is most urgently needed. The short-sightedness of the system which, partly to save a few pounds and a little trouble, and partly to make a "vain show," converts a *trial* into a *trip*, must be strongly condemned, and we hope that it may not be long before marine engineers in general will see with us, that it would be to their interest to do thoroughly and well that which so many of them now expend much trouble in doing in a useless and incomplete fashion.

ON THE ADVANTAGES OF A CONSTANT AS COMPARED WITH AN INTERMITTENT WATER SUPPLY.

From the "English Mechanic."

At the recent meeting of the British Association at Belfast, Mr. Deacon read a paper on his water-waste meter. In the discussion which followed, Mr. F. J. Bramwell, C. E., made some valuable observations. He said: I believe that most serious injury to health has been occasioned by the system of cistern storage. Cisterns are of necessity cumbrous. They have to be put somewhere out of the way, and commonly careless or ignorant builders or architects fix them in all but inaccessible places, where they are out of sight and out of mind, and thus attention is not paid to keeping them clean, and all sorts of filth accumulate; but, bad as this is, it is not the worst result of the system, for too commonly the cistern for general purposes is placed in close proximity to that part of the house from which it ought on every ground of health and of common decency to be the furthest away, and it appears as though the very effort of the constructors of such houses is to make arrangements for the express purpose of contaminating the water. Those who travel on the suburban railways of London and observe the backs of the poor dwellings in the neighborhood of some of those railways, must have noticed that commonly the only cistern was exposed to the full heat of the sun, and was carried on the top—in fact, formed the roof—of an outbuilding from which filthy gases emanate to be absorbed by the water, and thus that which should be the source of cleanliness and health was fouled and poisoned as a preparation for its use. That water can be rendered the carrier of disease by the absorption of foul gases, I presume few present will doubt; but I may refer you to a recent statement in the *Times*, where it was shown that typhoid fever had been communicated to a number of cottages by the vapor from a drain in which the slop-water of the washing of the linen of the first patient suffering from that fever had been thrown. By placing cisterns where they could receive foul gases, I have no doubt but that disease might be spread through a house; but worse than this, the intermittent system is attended (when the supply is shut off, and the lower cisterns are filling from the water remaining to the higher parts of the pipes) by an indrift into the general service main, and in this manner, as is well known, foul gases, in some cases even foul liquids, had been drawn into those mains; and thus the disease is laid on from one house to another.

The constant service affords an agreeable contrast to this catalogue of loathsomeness. The water being always at full pressure in the pipes, all that is required is to turn the tap and draw the water cool, and as pure as it may be when supplied, unpolluted by foul gas or by foul liquid. But it is said by those among water-works, engineers and managers who still advocate the intermittent supply, that even assuming all these things to be true, the intermittent supply is a necessity, and that the waste of a commodity that is not paid for according to the quantity used, but is paid for in an annual rate, must be so excessive if the service is constant, that whatever may be the evils of intermittent supply, they must be submitted to, as the only means of preventing gross and unbearable waste. But the fallacy of these arguments has been exposed, and so successfully exposed, by the advocates of the constant supply, that the Legislature has for many years past insisted on inserting in each Act for the supply of water to provincial towns a clause to secure constant supply; but this legislative care is operative in provincial towns only, and there is one most important exception to this otherwise now general rule, and that exception, unhappily, is in the case of the metropolis.

In London, with its three and a half to four million inhabitants, the water supply is given over to eight companies, who reign supreme; the metropolis is divided into districts, each company has its own, and there is no competition, no new company is permitted, and London is powerless. Various checks have been suggested, and some have even come into operation; but the result is that, practically, the companies do as they please. Many years ago an Act was passed to give a constant supply to London, but the section will see that it is a perfectly dead letter when I tell the members that before a company can be compelled to afford a constant supply it must be demanded by a large majority of the inhabitants who are served by a "district main." It turned out that the term "district main" had no recognized meaning, and that it was impossible to tell what group of houses would satisfy this term; the result was, the Act was never put in force. About three years ago an Act was passed to cure the blunder in the former Act, and to obtain a constant supply for the metropolis. One of the provisions of that Act is that within six months the water companies should frame a set of regulations for the "fittings," and that those regulations should be submitted to the Metropolitan Board of Works, who, if they disapproved them, were to be heard before the Board of Trade. The eight companies drew up their regulations. The Metropolitan Board of Works did me the honor of referring these regulations to me for examination and for a report, and, as I considered them most oppressive, I advised they should be opposed. I trust the section will bear with me when I mention one or two of the clauses of the regulations. The use of cisterns must be continued; nevertheless, all the pipes in the house must be replaced with pipes of a great strength, unless, indeed, they happened to be of the excessive thickness demanded, which, however, was most unlikely. If there were a bath in the house, it must only have one opening for inlet and outlet, so that the clean water must come in through the dirty outlet. Moreover, it must not have a waste-pipe, because the water might be left on accidentally, and, if so, the owner would be punished by the bath overflowing and spoiling his ceilings and walls, and, perhaps, a few pictures. Cisterns were not to have any overflows except of a particular kind—that is, they were to be brought through the house wall into a place where the officer of the company could see them. When it was objected that this would in many cases involve great length of pipe and serious cutting away of plasters in order to carry the pipe down within the house to about the pavement level before bringing it through the wall, it was said, "Oh, bring it out through the nearest wall at whatever floor the cistern may be"; and the representatives of the company did not see any particular objection in the fact that any householder who did this would be liable to an action for damages for suddenly giving a shower-bath to a passer-by, and they seemed to think the suggestion that ladies would not like to have good dresses or bonnets thus spoilt an idle one. The commissioners before whom the regulations were discussed, very greatly modified them in favor of the public, but nevertheless the Act is still practically inoperative, and probably will be till another outbreak of disease causes fresh alarm.

During the discussion on the question of constant supply to London, the advocates for it instanced Norwich, where, under efficient supervision, the consumption per head fell from between 25 and 30 gallons per diem on the intermittent system, to 15 gallons on the constant; Manchester, a large city, where the result has been nearly as markedly favorable in relation to the constant supply; and Sheffield, a town where it has been most successful, the supervision there having brought down the consumption to many gallons per head less with the constant than with the intermittent supply. On the other hand, the supporters of intermittent supply in the metropolis have said: "Look at Liverpool; here is the case of a town which began on the constant supply, and had to give it up, the waste was so great." No doubt this was so, and it was always felt to be a powerful argument in favor of the London advocates of an intermittent supply. They said, in effect, the requisite supervision becomes unfavorable in large towns (although Manchester was a success), and thus Liverpool was made a standing reproach to the constant supply system. Liverpool was on the intermittent service when Mr. Deacon was selected to be the engineer to the Water Committee. Happily for Liverpool and happily for the question of constant service, Mr. Deacon was not content to fold his hands and put up with things as he found them without an attempt to better them. He saw the expense and difficulty attendant upon a house-to-house inspection of the state of the fittings; he knew how offensive such inspections are to those who are behaving properly and honestly; and he set himself to devise an instrument by which he should be able to form a very good idea in which houses waste was going on, and to inspect those houses, and those only. His reflections on the subject had resulted in the water-waste meter which was now before them. This had been successfully in operation in several of the districts where the Water Committee, before determining on adopting it generally, thought it advisable to have an independent opinion on the subject, and they requested me to investigate into and report upon it. In consequence of this request I put myself into communication with Mr. Deacon, and visited Liverpool. I first tried the meter, under very varying heads, delivering water into tanks of known capacity, to ascertain the correctness of its registration. This I found to be very satisfactory. I then spent the greater part of two nights in the streets of Liverpool, going with the inspectors through two districts to which the meters had just been applied. The results were most striking. On visiting one of the meters at midnight, it showed a consumption of about 3,000 gallons an hour. Going on, passing through the district, the inspectors applied the key to the stopcock outside each house, and, on the ear being put to the top of the key, the presence or the absence of sound indicated whether there was water running through or not. By closing the cocks when the noises were heard, and leaving all the others open, it was found on revisiting the meter that a waste of 2,200 gallons an hour had been arrested. The few houses where the stopcocks had been closed were noted, and these houses alone were the subjects of visits from the inspectors on the following day. I believe the apparatus is one which may be thoroughly relied on as not likely to get out of order, and that it would enable perfect control, at the least possible cost and with the least annoyance to the inhabitants, to be maintained over a district; and I think the Corporation of Liverpool are to be congratulated for having selected as their engineer a gentleman who, by his intelligence and inventive talent, will not only save the Corporation many thousands a year, but will restore the boon of constant service to Liverpool; and I further think the advocates of that service throughout the country, and all those who are interested in sanitary science (in truth, that means the whole population), are indebted to Mr. Deacon for having made this important improvement in facilitating the adoption of constant service.

ON MODULES.

From "Engineering."

Hydraulic engineers not having yet arrived at a perfect module for measuring the amount of water drawn off in an open channel for irrigation or other purposes from an open canal or reservoir, under a varying head of pressure, it is a matter of some interest to examine the older types of design of modules that have been used at various times and in various countries, before going on to those of more modern form. The designs being necessarily simple, they will be found perfectly comprehensible by means of description without the aid of drawings or diagrams.

Piedmont appears to have been the birthplace of modules, for although irrigation is essentially Oriental in origin, owing to its extreme reproductive power in hot climates, and though it was introduced into Europe by the Moors, we do not find, either in India or in Spain, where portions of these works still exist, anything approaching to a module. The systems employed in carrying out irrigation almost proved that they had not such a thing at all. In India the practice seems to have been to turn water on to a field until either the land-owner or the turner-on of water was satisfied, or perhaps rather until the land-owner was satisfied that he could get no more. No doubt this was the best plan to start with, as the object of irrigation was to water the fields sufficiently, and the land-owner being the best judge as regards how much water was required for his crop, this mode insured the observation of the proper persons. This plan was, however, open to one very serions objection; when the land-owners discovered that an extra amount of water beyond that strictly necessary for the crop was in some cases capable of increasing the amount of produce to a small degree, they would take more water, either by stealth or otherwise; the amount of perpetual squabbling on this subject would then have been very large, had it not been for the fact that in Oriental countries irrigation works were made by rajahs, emperors, or chiefs, whose despotic rule and despotic institutions supplied a very practical limit in such matters—moral or physical force. In Spain, under Moorish rule, it is probable that this useful substitute for modules was also in vogue; but in the huertas, or irrigated lands, of Spain in more modern times, and under Christian rule, the water being the joint property of several villages that combined to keep the works in order, and legislated for themselves about the distribution of the water, the first great step, the just division of the water on a large scale among the several villages, had to be regularly carried out. The canals being on a small scale, the division was effected by equalizing the size of a certain small number of outlets from the main canal into the subsidiary channels; one village thus taking a fourth or a sixth of the total volume of water passing down the canal.

In Piedmont the conditions were different; the country being hilly, and the water taken from streams and torrents having a considerable fall, water power was extensively used for driving corn mills. It is probable that there were a few water-driven corn mills both in India and in Spain, but there such mills would be a public institution, the miller being a servant of the community, generally living on a fixed income, or yearly pay, given either in kind or in money by all the neighboring villages using the mill. In Piedmont the mills were the private property of individuals, as they are at the present day in Europe; hence it was there that the first unit of water measurement was arrived at—the amount of water enough to drive a corn mill, which were probably then and there of about the same size and requirements. This amount of water then assumed a technical name, the *ruote d'acqua;* the same thing in Lombardy being called a *rodigine*, in Modena a *macina*, and in the Pyrenees a *moulan*—the same circumstances in various places leading to the adoption of a similar unit of measurement, which was naturally rather variable. In Piedmont the amount was generally about 12 cubic feet per second, and was supplied by an outlet 19 in. to 20 in. square, the water issuing free from pressure at the surface level. The next step was the introduction of a smaller unit of measurement for purposes of irrigation for discharges under pressure, the Piedmontese *oncia;* which was a rectangular outlet 5.04 in. broad, 6.72 in. high, having a head of water 3.36 in. above the upper edge of the outlet; its discharge was 0.85 cubic feet per second, and this was the immediate parent of the Piedmontese module, and, as far as we know, the ancestor of all modules.

Piedmontese Modules.—These, the most perfect type of which is that of the Sardinian code, were designed or intended to fulfil the following conditions: that the water should issue from the outlet by simple pressure, that this pressure should be maintained practically constant, that the outlet should be made in a thin square plate having vertical sides, that the issuing water should have a free fall, unimpeded by any back-water, and that the water of the canal of supply should rest with its surface free against the thin wall or stone slab in which the outlet was formed. The following is a description of the general type: The water is admitted through a sluice of masonry, having a wooden sluice gate working vertically' into a chamber in which the water is supposed to lose all its velocity, and is kept to a fixed level mark by raising or lowering the sluice gate; the chamber is of masonry and has its pavement on the same level as the sill of the sluice, the regulating outlet from this chamber being an orifice 7.854 in. square, having its upper edge fixed at 7.854 in. below the fixed water level mark of the chamber. Its discharge is 2.04 cubic feet per second. If a larger discharge at one spot be required, the breadth of the outlet is doubled or trebled, the other dimensions remaining unaltered. Such are the sole unalterable conditions or data of this module; all its others seem to have varied very greatly; its sill is sometimes on the level of the bed of the canal of supply, sometimes above it, and sometimes below it, in which case a slight masonry incline was made from the bed down to it; the length and breadth of the chamber vary greatly, the former from 15 ft. to 35 ft., its form being circular, oval, or pear-shaped; the side walls splaying outwards sometimes close up to the sluice, sometimes not till near the regulating outlet, the object being to destroy the velocity of the water within the chamber. The lower edge of the regulating outlet is generally, but not always, placed at 9.825 in. above the floor of the chamber. The paved floor of the chamber is in many cases, but not in all, continued at the same level beyond the outlet.

The practical advantages of this type of module consist, therefore, in having a chamber in which the water can be kept to a constant level, and hence from which the water can issue under a constant head of pressure through a regulating orifice of fixed dimensions.

Milanese Modules.—The *modulo magistrale* of Milan is the most improved type of Lombardian modules, the *modulo* of Cremona and the *quadretto* ot Brescia being very inferior to it in design; its principal advantage over the Piedmontese modules being the fixity of dimension of almost all its parts; in other respects it resembles it very much, the principal differences being that the water chamber is always rectangular and covered by slabs, and is hence called the covered chamber, that its flooring has a reverse slope in order to deaden velocity, and that the masonry channel beyond the regulating outlet has fixed dimensions also, a portion of it being called the outer chamber. As to its general arrangements, the sluice of supply has its sill invariably on a level with the bottom of the main canal, which is paved with slabs near it; the breadth of the sluice is the same as that of the regulating or measuring outlet; the sluice gate is worked by lock and level, being fixed and locked at any required height by catch lock and key. As to dimensions, the covered chamber is 20 ft. long, its flooring having a rise of 1.75 in. in that length, and its breadth is 1.64 ft. more than that of the sluice of supply; that is, .82 ft. more on each side; the lower surface of its covering of slabs or planks is fixed at 3.93 in. above the upper edge of the regulating outlet, which is the height to which the water must be kept to secure the fixed discharge. In order to gauge the water in the chamber, a groove is made in the masonry so as to allow a gauge rod to be introduced within at the sill of the sluice, which will read 27.51 in. of water above the sill when the proper head of pressure exists; should it read more or less, the sluice gate must be raised or lowered. The outer chamber is 7.86 in. wider than the measuring or regulating outlet, its total length 17.79 ft.; its side walls, which like those of the covered chamber, are vertical, have a splay outwards, so that the width at the further end is 11.72 in. greater than at the outlet end; that is to say, it is there equal in width to the covered chamber. To insure a free fall, the flooring of the outer chamber is 1.96 in. below the lower edge of the outlet, and has besides a fall of 1.96 in. in its length of 17.72 ft.

The total length of the module is nearly 37.75 ft., but its breadth is variable, according to the amount of discharge required. If intended to discharge a Milanese *oncia magistrale*, the Milanese unit, which varies from 1.21 to 1.64 cubic feet per second according to different computations, say, 1.5 cubic feet per second, the measuring outlet is 7.86 in. high and 4.12 in. broad, under a constant head of pressure of 3.93 in.; the breadth of the covered chamber being 25.54 in., and the breadths of the open chamber 13.75 in. and 25.54 in.

It is essential to the effective operation of the regulating sluice that the difference of level between the water in the canal and that in the module be at least 7.86 in.; and as the height of water in the latter must be 27.51 in., the depth of water in the canal must never be less than 35.37 in. or 3 ft., in order to allow the module to work properly. The following are the relative levels of the parts of the module, referred to the bottom of the main canal as a datum:

	Inches.
Water surface in the interior of the module	27.51
Upper edge of the measuring outlet......	23.58
Upper end of flooring of open chamber...	13.75
Lower end of the same....................	11.79

Such is the type of the Milanese modules, the dimensions being suitable for a discharge of 1.5 cubic feet per second; unfortunately, in point of fact, the type has been rarely rigidly adhered to, and thus its advantages as a universal, or even as a local water standard have been comparatively thrown away in practice. Its use, however, established a discovery that was at that time very important, viz: that larger outlets gave a greater discharge than that due to the proportion of their section for small ones; it was therefore determined that no single outlet of a module should be made for a discharge of more than eight oncia or 12 cubic feet per second; when more than that was required, two or more separate outlets could be used in the same module, or combination of modules. A gauge post was also found to be necessary in order to enable the water guardians to adjust the sluice accurately.

The principal defect of the Milanese modules is that, owing to the rush of water from the canal, it is nearly impracticable to keep a constant head of pressure on the measuring outlet; besides this, sand and fine silt vitiate the accuracy of amount of discharge.

Such are the comparatively ancient modules, the Milanese *modulo magistrale* being the most improved one of them. Their type has been very much adhered to in modern times; that of Messrs. Higgin and Higginson on the Henares Canal may be considered as the greatest improvement that can be made on them, without departing from that type. In this module, the entrance by a sluice into a chamber for destroying velocity has been preserved, but the exit is an overfall, and hence more susceptible of exact measurement of discharge; the means applied to deaden the velocity of entrance are again different.

The entrance into the channel through a wall is a passage 23.6 in.(.6 metre) square, regulated by a well-fitting cast-iron door raised by a screw; the chamber is rectangular, 10.37 ft. long by 7.20 ft. wide below, 9.20 ft. above, the side walls having a batter of 1 in 6. The bottom of the chamber is horizontal and at a level .72 ft. below the sill of the entrance sluice. To deaden the action of the water, a partition of masonry grating work is built across the chamber at a distance of 4 ft. from the wall, and 5 ft. from the overfall wall of exit, it is 1.37 ft. broad, and has eight slits or vertical passages not crossbarred, each slit being 5.4 in. wide. The water having been deprived of all action by passing through this arrangement, enters the second portion of the chamber, and then passes over a weir having an iron edge 6.56 ft. (2 metres) long, fixed nearly on a level with the top of the entrance sluice, or 2 ft. above its sill. The discharge required for irrigation being never to exceed 176 litres or 6.22 cubic feet per second, the depth on weir will therefore never exceed .5 ft., the sluice opening being 1.97 ft. square.

There are two small side walls having a batter from above on either side of the sluice entrance, these walls projecting into the main canal, in order to protect the entrance and prevent silt from accumulating there, which otherwise, and perhaps even in any case, would have to be dug out occasionally. In order to keep the chamber in proper working order, a keeper must be employed, and a gauge post erected in the canal, with reference to which he lowers or raises the sluice, and keeps the water in the chamber always at a fixed level.

It is evident that the changes may be rung on this species of module to a great extent without effecting great improvement, by increasing the number and altering the positions of the sluices and overfalls, and modifying the arrangement for deadening the action of the water. This has been done in many cases without much result: it is hence not worth while to bring forward other examples of this type, especially as also the occasional attendance of a keeper is absolutely necessary for all these modules.

THE DIAMOND ROCK-BORING DRILL.

BY MAJOR BEAUMONT, R.E., M.P.

From "Journal of the Iron and Steel Institute."

All new applications of machinery must, in these times of high-priced manual labor, have a peculiar interest, especially to such a body of practical gentlemen as that which I now have the honor to address; and the application of the diamond to the general purposes of mining will, I think, be allowed to be producing results well worthy of your attention. I appreciate fully the value of time, and shall, therefore, proceed at once to my subject, without making any introductory remarks, or referring to other means of doing the same work as is done by the Diamond Drill, except so far as may be necessary to explain the difficulties which it is asserted the system under discussion overcomes. The patents for the Diamond Drill are extensively worked by the Diamond Rock-Boring Company, the results previously obtained having removed the system from the category of experiment, and established it as a recognized and practical success. As a rule, the Company neither sell machines nor let them out on royalty, but contract, at a fixed price, for the execution of work. The business taken up by the Company divides itself into four classes, in some of which a greater advance has been made than in others.

1. The sinking of bore holes for the purpose of testing or prospecting for minerals.

2. The driving of drifts, galleries, and tunnels, whether for mining, waterworks, or railways.

3. The sinking of shafts.

4. The removal of subaqueous rocks by blasting.

All of you will have a general idea of how these operations are carried on. Still, in order to enable you to value the results obtained with the Diamond Drill, I shall recall the leading features of the position in which the application of machinery stands with reference to them.

1. Bore holes are ordinarily put down by giving a reciprocating motion to a chisel attached to the end of rods, lengthened as the hole is deepened, the *debris* being brought up by means of shells or augurs. This reciprocating motion is given either by manual labor or by power. A considerable difficulty and risk attends giving even a very moderately rapid reciprocating motion to a long column of rods, and to get over this difficulty, and facilitate their withdrawal, Messrs. Mather and Platt have constructed machinery whereby the cutting is done by the fall of a tool suspended from a rope, the great point of gain being the speed at which the necessary tools, either for cutting or removing the *debris*, can be lowered to their work and withdrawn. Attempts have, moreover, been made to apply a rotatory motion to steel cutters, but even in soft rock the progress so obtained has been extremely slow, because no steel can be got to withstand the abrading action of the rock.

2. Headings are ordinarily driven by drilling holes and blasting them. Machinery is applied to the drills by attaching them to pistons, actuated by compressed air in cylinders, a supply of water to clear the *debris* and cool the tool being used. The air is distributed by a valve, or valves, driven by suitable mechanism, and a rotating motion is given to the tool to obviate its striking two blows in the same place. All the percussive systems of boring machines in actual use come under the above description, varying in the greater or less degree of mechanical skill with which the parts have been arranged.

Some machinery has been made which proposes to drive tunnels, at one operation, entirely by machinery, and without the use of powder; but, hitherto, so far as I know, only a few yards have been so driven experimentally.

3. Drills similar to those applied to tunnel driving have been used for shaft sinking, but only singly, and I have not heard of any case where the speed of the sinking has been notably increased.

4. The putting down of blast holes under water has always been considered a most difficult operation, because a blow cannot be struck under water, and I have

never heard of machinery being applied in this direction at all. I saw, on the Suez Canal, rocks being removed by blasting, but the holes were put in by ordinary churn jumpers, worked from barges anchored in the stream.

The Diamond Drill is, in principle, quite distinct from any other system of holing rock, and works by rotation without striking a blow. Its action is rather that of abrading than cutting, and its effect is produced by the sheer difference in hardness between the diamond and the rock it is operating upon. There is really no comparison between the hardness of the diamond and that of ordinary rock. If a diamond be kept rotating against a sandstone it would cut a hole, say a mile deep, before it was seriously worn. It will be seen at once that if this wonderful resisting power be properly taken advantage of, a machine can be constructed that will hole rock without striking blows. This enables machinery of the simplest and most ordinary character to be used, and thus avoids those special difficulties that the mechanic must face when he is driven to utilize a large power in the production of percussive action; moreover, machinery can be applied in places where a reciprocating motion, if admissible at all, would present peculiar difficulties—such as making a hole under water, or putting down deep holes where, from the circumstances of the case, the cutter must be at a great distance from the source of power.

The diamonds that are used are not valuable gems, but carbonate, a substance that till lately had no commercial value, and was first introduced for the purpose of cutting other diamonds. It comes from the Brazils in considerable quantities, and though it has not yet been discovered in the Cape diamond fields, it is more than probable that it exists there, and, indeed, wherever the diamond is found. You will see that its appearance is much like that of a piece of coal, or dull jet, and as unlike as it is possible to be to its brilliant sister, the ordinary diamond, though chemists tell us that the two are identical in composition. I presume that one is perfectly, the other imperfectly crystallized; and, if so, it is, no doubt, this very imperfect crystallization that gives to carbonate its value for my purpose, as it has no, or next to no, cleavage, and consequently does not split up and break in the way that a diamond or piece of boart would do. This last substance, of which I hold a sample in my hand, is an impure diamond, and would seem to stand half-way between the brilliant and the carbonate. According to the tables published in Ure's "Dictionary of Arts," the following are the different specific gravities and degrees of hardness of some of the hardest stones:

Substance.	Hardness.	Sp. Gravity.
Diamond from Ormus	20	3.7
Pink Diamond	19	8 4
Bluish and yellowish	19	3.3
Ruby	17	4.2
Pale ditto from Brazil	16	8.5
Deep blue sapphire	16	3.8
Ditto paler	17	3.8
Topaz	15	4.2
Whitish ditto	14	3.5
Emerald	12	2.8
Garnet	12	4.4
Agate	12	2.6
Onyx	12	2.6
Quartz	10	2.7

Now, as there is plenty of corundum or rubies and sapphires in the market at mere nominal values as compared with those of carbonate, I thought they would be advantageously used in place of the latter, if only their hardness, as compared with the diamond, was anything approaching that which the tables led me to look for. On trying, however, both sapphires and corundum, I found the above proportions altogether wrong in point of hardness: they were nowhere near carbonate. The trial that I put them to was as follows: I set a piece of carbonate in a suitable holder, and held it against a grindstone: the carbonate turned the grindstone down. On trying the same experiment with the other minerals, the grindstone wore them down. I am of opinion, therefore, that the diamond stands, in point of hardness of resistance to abrasion (if the two are not synonymous terms), at an enormous difference in advance of any other known material in nature, and this seems a most remarkable fact.

The application of the diamond to rock-drilling is worked out as follows: The stones are set in an angular ring, made of steel; they are fastened in by making holes as nearly as possible the size of the stones to be set, and then burying them, leaving projecting only the amount necessary to allow the water and *debris* of the cutting to pass; the metal is then drawn round the stone so as to close it on every side, and give as large a bearing surface as possible to resist the tendency of the stone to be forced out. I may here say the loss from breakage and from the stones being torn out is far more serious than from wearing; in fact, with good stones having good broad running faces, the mere wear is quite trifling. A stone breaking out is always a cause of damage to the others. The crown so set is attached to the end of a steel tube and kept rotating against the rock at some 250 revolutions per minute. Water is supplied through the hollow of the bar, whence it passes under the cutting face of the crown to the surface of the hole between the side of the latter and the outside of the boring tubes; the diamonds are thereby kept cool, and the *debris* from the cutting is washed away. The crown has to be kept pressed forward with a force depending on the nature of the rock to be cut, varying from 400 lbs. to 800 lbs., when the cutting is done at speeds ranging from 2 in. to 4 in. per minute. Granite and the hardest limestones are readily cut at 2 in. to 3 in. per minute; sandstone at 4 in., and quartz at 1 in. per minute. These speeds can be increased at pleasure, but I give them as representing the rates at which the drills are ordinarily run in practice.

On the table is a sample of pure emery, which was cut at the rate of 2 in. per minute, by a crown which I now hold in my hand; and which has bored through 6 in. of emery, 10 ft. of granite, and 95 ft. of hard sandstone; you will see that it is, so far as the diamonds are concerned, almost as fit for work as ever. The emery was cut out of a block put under the drill for experimental purposes, merely to show how great is the cutting power of the diamond. No rock is met with in mining that approaches emery in hardness, and, indeed, it would be a most difficult operation getting a hole put in it without a Diamond Drill.

The cutters travelling in an annular ring, it follows that a solid core is produced, an arrangement which, while it ensures a minimum of work being done to make a given-sized hole, affords evidence of the strata passed through, a fact which is invaluable for certain applications. Having explained the crown, and the way in which it cuts, I shall now describe the machinery for utilizing it. 1st.—For prospecting. The drawings on the wall show two views of a prospecting machine, which are in all essential particulars the same as those now being used. The crown is screwed on to the end of steel tubes, which are successively lengthened as the hole is deepened, the bars pass through a drill, and are gripped by a universal clutch, which causes them to turn. Set screws on the top of the quill steady them centrally at their upper ends; the quill is attached to a cross head which slides between two vertical uprights, and weights are provided, working over pulleys, by which the weight of the boring-rods and cross head are either increased or balanced, when extreme depths of holes are reached. The water is supplied by a force pump passing to the hollow bars through the union at the top of the quill. The other gearing about the apparatus is for raising and lowering the rods by power. It consists of a crab, and the lifting is done by means of a chain or rope passing over a pulley attached to shear legs across the hole. Two descriptions of boring tubes are used, as shown by the sketch, one of which is more expensive than the other, but it is stronger, and at the same time being nearly flush on the outside, there is less risk of the rods jamming in the hole. Suitable tackle is provided for recovering the tubes when they break, and their hollow form makes them peculiarly easy to get hold of. It very rarely happens that any are permanently lost. The usual plan for lifting them is a taper tap which enters into the hollow, when a few turns suffice to get a firm grip. The following table shows the dates on which some bore holes have been commenced and finished-and at this moment the Diamond Rock, Boring Company have over thirty machines either at work or about to commence, all of which are keeping fully up to the average of speed there shown.

I beg to read one of the many certificates given, as I think that independent testimony of work actually done would be more satisfactory than any statement of mine:

"DUNDRAW, WIGTON, *June* 2, 1873.

"TO MAJOR BEAUMONT, R.E., M. P.

"DEAR SIR: I feel that I should not be doing my duty to the Diamond Rock-Boring Company without adding my testimony as to the speed, excellency and satisfactory manner with which your Prospecting Machine (No. 14) has done its work for me in Ireland. The Borehole at Ballycloghan was commenced on the 7th of April and completed on the 23d of May, when a depth of 558½ feet was reached, the whole of which was bored through hard basalt and whinstone. During this time the machine was ordered to stop for a week for consultation with another gentleman as to the advisability of going deeper; and, allowing for this, and also Sundays and wet days, the daily average was within an inch or two of 20 feet per day, and upon two days a depth of over 40 feet each day was bored at one time, and in the presence of myself and several other gentlemen, the machine was boring at the extraordinary speed of 3 inches per minute (whinstone). An enormous quantity of core was daily extracted, and a complete section with perfect specimens was easily made. I may add I hope soon to require another machine or two to bore near here and in Scotland.

"I am, yours very truly,
(Signed)
"R. A. WATSON, C. E."

STATEMENT SHOWING RESULTS OBTAINED IN SOME OF THE BOREHOLES EXECUTED BY THE DIAMOND ROCK-BORING COMPANY.

Locality.	What for.	Including getting Machinery on the Ground, &c. Commenced.	Ended.	Actual Working Days.	Depth.	Remarks.
Girrick..........	Ironstone....	1872. Oct. 1	1872. Nov. 30	54	ft. in. 902 0	Ironstone.
Moorsholme....	"	June 1	July 27	48	641 0	Ironstone found.
Fishburne......		Nov. 9	1873. Feb. 1	54	434 0	Coal found.
Beeston........	Coal..........	1873. Feb. 22	July 22	146	1,008 0	Boring stopped on the 22d July.
Chewton.......	"	1872. Dec. 31.	July 13	168	802 0	Boring stopped, and commenced in another place.
Wollaton.......	"	1873. Feb. 16	April 12	48	700 0	Commenced boring at 387 ft. below the surface of the ground. At 452 ft. passed a seam of coal 1 ft thick; at 587 ft. a seam 6 in. thick; at 654 ft. 6 in. a seam 4 ft. thick; at 696 ft. through a seam 5 ft. 10 in. thick.
Loftus.........	Ironstone....	Mar. 16	June 7	60	640 2	Ironstone found.
Ballymena......	Coal..........	April 7	May 24	42	558 5	Nothing of value discovered.

The greatest speed attained was at Waluff, in Sweden, when 304 ft. 6¼ in. were put down in one week.

In soft strata, such as clay, sand and alluvial deposit, the diamond system is of no use, and in such ground we always use the ordinary method of boring, turning to the diamond directly rock is reached. I may add, however, that the boring tubes, pump for supplying water, and the whole arrangement of prospecting machinery (irrespective of the diamond crown), is found of great use in getting through the soft, and fixing any necessary lining tubes. The actual speed of cut is the same as that previously quoted. There is, however, no advantage in cutting at so rapid a rate, as the time employed in actual boring is as nothing compared with that which is consumed in lifting and lowering the rods. Different distances are bored without lifting, according to the nature of the strata, and the necessity for obtaining information. The core, when formed, is passed into a core tube, and is kept from falling out on withdrawing the rods by means of sliding wedges or clips, which allow the core to pass freely up, but prevent its returning. The great advantage claimed for this system of boring consists in the speed obtained—work being done in less than months that formerly took years, and in the fact that sample cores of the strata passed through are obtained. To realize the benefits likely to accrue from these facts, one must remember the unsatisfactory evidence afforded by the powdered material brought up by the ordinary method.

Shafts have sometimes been put down

in wrong places; and it is always of importance to know the strata to be sunk through; hence, I think, in future, few pits will be sunk without first accurately testing the ground by actual boring. Unless such a speed as the Diamond Drill gives were possible, this course could not be followed, as, though it might be well worth while to delay a sinking for a month or two for perfect information, it would be quite impossible to do so for the same number of years.

Turning to tunnel driving, you have before you a drill such as is actually used for that purpose, the leading features of which are that the drill shaft is screwed, and is driven by means of a longitudinal slot and feather. Gravity, as in the case of the prospecting machine, cannot be used; hence the advance is given by a nut driven by differential gearing. The feed would be positive were it not that the connection between the nut and the driver is by means of a friction break around the former. The break is held together by an adjustable spiral spring, and one of the lugs to which this spring is attached forms the driver of the nut; hence, when the power necessary to drive the nut exceeds the compression at which the spring may be arbitrarily set, the break not only slips but is actually taken off the nut. This arrangement has never failed in practice, and the drills may be relied upon with absolute certainty to relieve themselves whenever the pressure necessary to cut the rock exceeds a certain amount. Such an arrangement as this is necessary, since the rock is always variable in hardness. The drills, not being subject to the heavy blows which percussive action would throw upon them, are not more liable to deterioration than ordinary machinery. Some drills are now in good order, and at work, which were made three years ago, having since then cost next to nothing for repairs. Any number of drills that may be required are mounted on standards, which are connected with the air motor behind them, so as to be all driven from it. Each drill can be stopped and started independently, and as they work equally well, no matter how they may be angled, holes can be put in in positions where a miner would find it extremely difficult to work. The general arrangement of the company's tunnel-driving machinery is shown by drawings exhibited, and I would draw your particular attention to the method of fixing and removing the machinery. The jacks on the top of the standards fix the whole firmly in position, while on their being slackened and the standards tilted back, which is done by the machine itself, the whole is on wheels and free to move. Twenty minutes suffice ordinarily to get the machine ready for work, and it could be done in less time.

In applying machinery to driving headings, and speaking only of those machines that operate by holing the face of the heading, and use explosives, there are two broad systems of working, which have been followed. One is, to endeavor to imitate the action of the miner who seeks to put in his holes to the best advantage, watching each shot and angling the next accordingly, and putting down at the most three or four holes before firing. The other system is, to disregard the lay of the rock and the result of the previous firing, putting down such a number of holes as to make an absolute certainty of the rock being fetched to a given depth. All attempts to solve the question of tunnel-driving machinery by the first system seem to me to have failed, while the second, if fully applied, has always been successful. In practice, the principal difficulty consists in bringing forward and fixing the machinery, and its subsequent manipulation, and as all boring machines once fixed put down their holes in a very few minutes, it follows that ease of management and exemption from break-downs is a far more important element of success than mere rapidity of holing, which, indeed, all systems that I have seen possess. The following statement, taken from actual practice, will exemplify what I mean: In a gallery driven in compact mountain limestone, by the Diamond Boring Company, as an advanced heading for a tunnel in connection with the Great Western and Midland Railways at Bristol, thirty to forty shots were required to bring away the face, the holes being 3 ft. 6 in. deep, and an advance each shift of about 3 ft. 3 in. being obtained. Six drills were employed, their average speed of holing being 2 in. per minute, 30 holes at 3 ft. 6 in. = 105 ft. and six drills at 2 in. a minute = 1 ft. per minute, or the complete holing was done in 105 minutes = 1 hour 45 minutes, of actual working. As a matter of fact it was very good work to get the lot holed in four hours. Supposing now the drills had been speeded to 3 in. per minute, or 50 per cent. quicker, the holing would have been done in a little over an hour, which would have shown a saving of only half-an hour in four hours. My aim has therefore been to take a reasonable rate of speed like 2 in. per minute, and by so doing get certainty of obtaining a given result without break-downs, rather than trying for a *tour de force* in actual rate of cut. Exploding the holes is done successively, beginning with the central holes, which are angled, and progressing successively to the outside ones. At Mont Cenis, the length of their machines precluded the possibility of angling, hence they were driven to obtain a first opening by putting down larger holes in the centre of the heading, which were not fired. The Diamond Drill being shorter, enables the drills to be angled, and the centre is blown without the aid of empty holes. I think it likely this is the cheaper plan, but I am not clear that the Mont Cenis engineers did not choose the more expeditious one, as the fact of angling means a loss of progress.

In comparing the diamond system with the Mont Cenis or other good system of reciprocating drill, mounted in such numbers as to have a proper command of holing power, I do not contend that there is much advantage in favor of the former in point of speed, as in either case the holes can be put in any reasonable fixed time. I submit, however, that there is a certain gain, owing to the holes being true cylinders, and to the non-liability of the drills to break down, the machinery getting out of order being always a fearful source of delay. The great advantage claimed for the diamond system is its economy. No drills have to be sharpened, the plant is no more liable to get out of order than ordinary machinery, and the air in the motor can be used expansively, against which have to be set the wear of the diamonds, and the fact that the motor must be kept running whether one or six drills are at work. The latter disadvantages are, however, more than counterbalanced by the former advantages. The certificate of Mr. Brunlees, the engineer for the Bristol Tunnel, is as follows:

"Clifton Tunnel,
Westminster, May 13, 1872.

"To the Machine Tunnelling Company:

"Gentlemen,—Last week I had the pleasure of seeing your Diamond Borer at work in this tunnel.

"The material through which the tunnel is being made is hard mountain limestone, with numerous joints filled with calc. spar.

"The heading, which measures about 10 ft. by 8 ft., was previously driven by hand labor at an average speed of 9 1-2 ft. per week.

"The boring machine, during its first week of actual work, advanced the heading 26 ft., though the men only made eight shifts, the rate of progress per shift 3 ft. 3 in. The result of the week's work was, therefore, nearly three times that attained by hand labor, and it is only reasonable to assume that when the machine-men are fairly up to their work they will be able to bore 4 ft. per shift, and make twelve shifts per week.

"Hence there can be no reasonable doubt that the advance of the heading will become 48 ft. per week, or about five times that of hand labor.

"So far, the diamonds show no symptom of wear, nor have any of them got loose in the setting.

I am, gentlemen, yours truly,
(Signed) "James Brunlees."

SHAFT SINKING.

The plans on the wall show the plant which is now about to be applied to sinking two pits, each 700 yards deep, for Harris' Navigation Company, in South Wales. The shafts are not yet ready to receive the machinery, or it would long ere now have been at work. It will be seen the principle is the same as that which obtains in the tunnel-driving machinery, viz., a pair of girders or standards carrying as many drills as can conveniently be put on, which latter are driven by a double cylinder compressed air engine, and each drill can be stopped and started singly. The system of working may be the same as that which I have described for tunnel driving, but as the Diamond Drill bores a hole equally well 100 as 1 ft. deep, it is in contemplation to apply a new principle which the different circumstances which obtain in a shaft, as compared with a heading, render practicable. In place of drilling a series of holes 3 ft. to 4 ft. deep, the holes will be carried, at one operation, say 100 ft. deep. The machinery will then be removed, and the blasting continued, until the whole depth bored has been reached. The anticipated advantages of this system are that the machinery will only require fixing once; and further (which is the main point), the operation of drilling can be carried on whether there is water in the shaft or not. Of course, 100 ft. is an arbitrary depth, and as the drill never gets out of truth, there is no reason why the holing 500 ft. deep should not be done from the surface, or so soon as the rock may have been reached. I quite anticipate that since the holes are all straight, or nearly so, it will occasionally happen that there will be no free side to blow to, or, in other words, the shaft will be fast, but in that case it will be easy to free it by putting in a few hand holes. I am given to understand that in America this system has been tried with very favorable results, and I hope shortly to test it fully. If successful, the enormous difficulty which dealing with water always presents will be materially lessened, and a considerable economy both of time and money will result in sinking shafts, as the most tedious part of the operation, namely, the holing, can be done by machinery from the surface and irrespective altogether of the question of water. I shall have much pleasure in communicating to any one in Belgium interested in the subject, the results that may be obtained.

REMOVAL OF SUBAQUEOUS ROCK.

As regards the removal of subaqueous rocks, the drawings on the wall show the plant now being prepared to carry out a contract for the removal of rocks in the river Tees. The contract is between the Diamond Rock-Boring Company and the river Tees Commissioners. The work to be done consists in the removal of a scarp of rock 600 yards long by 200 yards broad, with an average of 20 feet of water over it at high tide. The rock is a terrible bar to navigation; it cannot be got away except by blasting, and to hole it by hand from a fixed stage would be a most costly and laborious operation. The plant consists of a barge, supported on legs, adjustable to suit the irregularity of the bottom of the river. It is provided with an engine and boiler, capable of driving 24 drills. That number of holes can be quite easily put down in a tide, as each hole 8 feet deep will not take more than an hour to drill. The dynamite, which is the explosive to be used, will be introduced through the same tubes which guide the drills, and the holes will be exploded so soon as the barge has been shifted to a fresh scene of operation. The arrangements are such that the holes will be loaded and fired without the employment of divers. A single drill has already been used on the rock to prospect it, and a few shots fired, sufficient to show that the designed interval of 10 feet from centre to centre of the holes admits of the rock being sufficiently broken up for dredgers to remove it, and at the same time the action of the drill under water was seen to be perfect. I give a general sketch of the machinery used for prospecting under water, and which was specially designed to meet the case of a rough sea; the single pile offers no resistance to the waves, and the power required to drive the drill can be conveniently taken from a barge or tug alongside by means of steam through a flexible tube. The Diamond Rock-Boring Company are offering to undertake the removal of the Daunts Rock near Cork harbor, and other sunken rocks in seaways; and for this purpose the Diamond Drill is submitted to be unrivalled, owing to the fact of its working as well in water as in air, and its being independent of the distance at which the boring may be carried on from the machine itself. In the limits of such a paper as this it would be impossible to go more fully into detail than I have done. The whole and sole claim to merit on the part of the Diamond Rock Drill consists in the fact that the use of carbonate enables rotatory to be substituted for reciprocating motion. Percussive machinery must, from its nature, be expensive, and, in some cases, it is especially difficult, if not impossible, of application. I have not alluded to the use of compressed air in tunnel driving, which is common to any system; but I may be permitted to say that the value of compressed air as an adjunct to mining, is only now beginning to be properly recognized, and in proportion as it is introduced for underground winding, pumping, and other purposes, so it will facilitate the introduction of machinery for tunnel driving, as the compressing machinery necessary for setting drills in motion becomes a serious consideration when it has to be put down for that purpose only.

DISCUSSION.

Mr. Steavenson had had the honor, two or three years ago, when in London, to be asked what his feeling was about driving a drift in Cleveland, and for that purpose using the rock-boring machine. It appeared to him at that time to be a machine which was useful in the main for working very hard stone or for very deep holes, and he then advised Major Beaumont that, as far as he could judge, the stone and rock in Cleveland was not such as would afford a suitable opportunity for employing his drill, it being very soft, and before he could even fix a large heavy machine like that, the material would be all to pieces. He (Mr. Steavenson) still thought that for very hard rocks and tunnels—where a number of holes had to be driven at one place, and for those alone—would that machine be found suitable for boring. He would be glad if Major Beaumont would point out to them how he managed in the event of his losing one of the diamonds in the head of the machine. He (Mr. S.) would like to point out one or two of the little weaknesses that had occurred to him, so that Major Beaumont might explain to them exactly the benefit of the invention, and how he overcame any little difficulties that he met with. The first and fourth heads were those under which it appeared to him it would be most useful, particularly for putting down holes in order to try hard rocks, and under that head he (Major B.) had not put it to them as he (Mr. Steavenson) thought he might take the liberty of doing, viz.: That it afforded an opportunity of seeing the exact nature of the rock, which no other system of boring did. When they got out those cores—supposing they were passing through a seam of coal or ironstone—they could see at once whether it was good throughout—whether it was mixed with band, or in what condition it was; and he knew that already in Cleveland a depth of 600 feet had been bored in about three months, and the nature of the seam was shown in a manner that was most valuable to those who wished to see the trial hole put down. There was another point to which he did not see that Major Beaumont had alluded. Instead of cutting out the hole, as was done in the old boring, he simply cut the circumference, thus having much less to do than with the common drill, and that enabled him to do the work with less labor. That was one great advantage, and one which he did not recollect hearing Major Beaumont mention in his paper.

Mr. Cockburn had the opportunity, a short time ago, of putting down one of the deep holes in Cleveland, by Captain Beaumont's machine, on a piece of ground that had not been proved before. They started the hole on the 8th of June, 1872—the depth was 641 ft.—and they finished it on the 25th day of July, although they had been standing still for something like two weeks for want of water for driving the apparatus. Not more than a quarter of a mile from the hole where that machine was put down, he (Mr. Cockburn) started to bore a hole by hand on the 6th day of July, 1871, and did not complete it until the 4th day of May, 1872, and he could safely say that the great difference between the hand boring and the machine tunnel boring was something that they could hardly fairly bring their minds to bear upon, for the simple reason that they could not get anything up out of the hole made by the old hand system of boring, but what was broken piece by piece into small dust, so that they then had very imperfect samples as the result of boring the holes, and more than that, they found great difficulty in boring holes of that description. If they got into a hard rock, they very frequently got chippings from amongst the *debris*, and the wearing of the chisels, which gave them a false impression of what they were raising as a whole, but on the other system they could get—as Mr. Steavenson said—borings that would show them the nature of the seam from end to end; they could, in fact, by the machine, get as complete a section as though they had the hole laid open before them, and it afforded him great pleasure to bear testimony to the expeditious and satisfactory way in which the Rock-Boring Company had done their work in Cleveland for Messrs. J. W. Pease and Co.

Major Beaumont said, with reference to the question that Mr. Steavenson asked, as to what he did when a diamond came out, he had only to say that he put another one in. The value of the machine turned entirely on the question whether the loss of diamonds was or was not covered by the value of the work that was done. The Rock-Boring Company had now a very large amount of carbonate, and they were continually buying. Sometimes they would bore perhaps 400 or 500 feet and the stones were barely touched at all, and there would consequently be next to no loss, so that 500 feet would then be done at a sum considerably below what the tools could be sharpened for; then, they would come on to rock where pieces of quartz were mixed up with the stone, or they might come upon that which was the worst material they had to deal with, viz.: a gravel conglomerate; the ground would suddenly pass from hard rock to soft, and *vice versa*, causing perhaps one stone to break, doing £7 or £8 worth of damage in a hundred revolutions; but if they averaged the total expenditure on diamonds, and compared that with the amount of work that was done, then—without absolutely mentioning an exact figure—he could say that the cost of the diamonds was well indeed within the value of the work that they did. With reference to the other point, that of tunnel-driving in soft strata, there was no doubt that that system of boring would not, and could not, in his (Major Beaumont's) opinion, work advantageously; the harder the rock, the greater the proportion that the labor of putting down the holes bore to the whole work that had to be done. Thus, if they took the two extremes, they might get a heading—and there were plenty of such in the coal measures—where, without using a machine, it could be driven at the rate of 5, 6, or 7 yards in a week. Where that was the case, he doubted whether they could do more than double that rate, and that at an increased cost. Then another extreme was, where it was very hard, he (Major Beaumont) had known a gallery where they could only do 2 feet to 2 feet 6 inches in a week, and in such a rock they could do in one year what would otherwise take 6 or 7. Then if they took the more ordinary cases—for instance, what he called a gallery in hard rock—say one that could be driven at an average of 3 yards a week, they would then bring that 3 yards up to five times that, and do at the rate of 15 yards a week. When they come to the question of cost, it was a very difficult one to enter upon, and he did not intend to do it then; but he might say broadly that when they took into consideration the question of putting down the machinery and providing the power—taking into account also the various drawbacks to its use—they would find that machines could not drive headings as economically as they were driven by hand, and if they added to the cost the royalties that had to be paid for the machinery, they would see that the cost of driving headings by machinery was certainly in excess of that for which they could be driven by hand, that excess representing from 1¾ to twice as much. The point then to consider as to the application of machinery was this: Is the fact of being able to do in one year's time what would ordinarily take from four to six years' time, worth paying so much more for, or is it not? He (Major Beaumont) could quite understand that in many cases, where it was desirable to open a mine rapidly, it was worth the owner's while to pay double, but in similar kind of work, where time is not so important, it might not be to the owner's advantage to pay double. They would permit him to say that he hoped the time would shortly come when they would be able to offer to the mining world something that would drive headings as cheaply by machinery as could now be done by hand labor. It seemed to him that machinery was being applied in all branches very successfully, and that that particular branch, viz., driving galleries by machinery, was, unfortunately, the most behind-hand of all. With reference to the other question asked as to the annular form, he had, he thought, touched upon it in his paper, but only very slightly, and after all—as they undertook to do the work—the question whether it required a little more or a little less power to drive the machine, was one that concerned the contractor rather than the employer of the machinery.

STEEL RAILS AS USED BY THE PRINCIPAL RAILWAY COMPANIES IN FRANCE.

From "The Universal Review of Mining."

The Minister of Public Works to the French Government made a collection of drawings, models, and books relating to engineering, to be sent to the Universal Exhibition of 1873, as he did in the case of the other international competitions that preceded.

Notwithstanding the short space of time which has elapsed since the Great Exhibition opened in 1867 at Paris, and the great drawbacks caused to ingenuity and to enterprise of all kinds by the misfortunes of the war, only those works were admitted which had been taken in hand or actively prosecuted since that time, and which had not been before exhibited.

The Minister has published a volume of notices, divided into two sections, in explanation of this exhibition.

The first comprises:

1. Documents relating to means of communication.
2. Maritime works.
3. Lighthouses.
4. Various subjects.

The second treats on mines.

In addition to this, an historical and statistical treatise on the means of communication in France, by M. Felix Lucas, engineer for highways and bridges, claims a place in this notice. On account of the general interest of the subject matter, the Administration have decided to authorize a separate publication of this treatise, which is divided into five portions, viz.:

1. Roads and bridges.
2. Railways.
3. Internal water communication.
4. Seaports.
5. Lighthouses and beacons.

Each of these heads forms the subject of a chapter divided into paragraphs, in which, after the official documents, the author collects the principal facts—historical, technical, administrative, commercial, economical, and financial—which bear upon the subject. Statistical tables, interspersed in the text, give detailed information on the most important points. The treatise is not brought down to a later date than the year 1870.

These two volumes contain documents and information of the highest interest, and we hope to give critical abstracts of the matters they treat of.

In this number we publish the remarks on steel rails as used by the principal French railway companies. At Vienna, the official Exhibition contains several samples and a portfolio of drawings.

Compagnie des Chemins de Fer de l'Est.

The Compagnie des Chemins de Fer de l'Est have had laid down, on those portions of its system where there is the greatest traffic, short lengths of permanent way with Bessemer steel rails supplied by the principal French works (Terre-Noire, Rive-de-Gier, Creusot, Saint Jacques, Montlucon and Imphy).

These rails, samples of which are exhibited, are of the Vignoles type, and of the same section as iron rails of 35 kilogrammes to the lineal metre, which have been for a long time in use on that company's system. Their weight, on account of the different density of the two metals, is as high as 36 kilogrammes to the metre.

Each rail, six metres long, rests on joint sleepers, with bearing plates, turned up on both edges, placed between; and upon six intermediate sleepers 90 centimetres from centre to centre. They are fixed by means of galvanized-iron wood screws.

An experiment was made by the Eastern Company in order to compare the relative endurance of steel and iron rails. In the month of March, 1866, a portion of the main line, at the terminus of La Villette, subjected to a great amount of traffic, was laid with sixty Bessemer steel rails and sixty iron rails, six lengths of iron alternating with six lengths of steel.

By the month of March, 1872, a gross load of about twenty-nine million tons had passed over all these rails, when thirty-one out of the sixty made of iron had already been taken up at periods more or less remote, and the wear which the remaining twenty-nine had suffered seemed to show that they were unable, taken together, to bear safely a mean greatest strain of twenty-four million tons; these iron rails were, however, of first-rate brands.

The steel rails, subjected to the same amount of wear and tear, were found to have only suffered a very regular wearing away, which was measured with the greatest exactitude by taking impressions from them in wax. This wear amounts to 1 millimetre for every twenty-six million tons where the traffic was normal, but is appreciably greater in places where the breaks were applied constantly, although even in that case the steel rails stood well.

The Eastern Company has also made some experiments on the relative durability of steel and iron rails, which have, in every particular, confirmed those of the Northern Company. They may be summed up as follows:

On being bent, the elasticity of iron rails commences to be impaired under a pressure corresponding to less than 25 kilogrammes per square millimetre, and their modulus of elasticity, E, is equal to 14.3×10^9. The resistance of steel rails up to the limit of elasticity rises to 38 kilogrammes, or one and a-half times that of the iron rails, and their modulus of elasticity is equal to 18.4×10^9.

Nearly all the iron rails break under a pressure of less than 8,250 kilogrammes, while all the steel rails stand up to 9,500 kilogrammes, which is the greatest pressure that can be attained by the testing apparatus.

With a monkey of 300 kilogrammes' weight falling upon the middle of a rail resting on two supports 1.10 metre apart, the mean height from which the iron rails were fractured is 1.60 metre, while that of the steel rails exceeds 4.60 metres; besides which, a greater portion of these rails could not be broken under a fall of 5 metres, the greatest momentum that could be obtained with the apparatus. At the same time, the steel rails, while being tested, lay on a cast-iron anvil weighing 10,000 kilogrammes, while the iron rails were supported by a framework of wood set in masonry.

It is, therefore, certain that the ratio of resistance to a bending strain in steel and iron rails of the same section is equal to 1.5 up to the limit of elasticity, and that the ratio of their relative resistance to fracture by a blow is even still greater.

These considerations have induced the Eastern Company to work out a standard for Bessemer steel rails of reduced section, as had already been done before by the Northern Company. The new steel rail of the Eastern Company will weigh 30 kilogrammes per metre, and will differ very slightly from that of the Northern Company. The joints will be made out of the perpendicular by means of fishplates, and the rail, 6 metres long, will rest on 6 intermediate sleepers distant 0.90 metre apart. The tendency to slip longitudinally will be counteracted by a special piece butting against the fishplate; this arrangement will prevent the necessity of notching the flange of the rail.

The data which we have just recorded were submitted to the superior administration, and by a decree dated 18th of last January, the Eastern Company was empowered to use on its system steel rails of the weight of 30 kilogrammes per metre. As the manufacture of the rails has not yet commenced, the Eastern Company were not able to exhibit a specimen.

THE MIDI RAILWAY COMPANY.

The Midi Company adopts steel rails on those portions of its system where the traffic is heaviest.

These rails, whether manufactured by the Bessemer or the Martin process, are supplied by the various French houses that have put up the plant necessary for carrying out these processes, that is to say: Imphy, Creusot, Terre-Noir, Firminy, and Commentry.

With few exceptions, all the rails in use on the Midi system are double headed, and their section is the same as that of ordinary iron rails.

	Metres.
Length of rail	5.30
Distance between centres of joint sleepers	0.60
Distance between centres of intermediate sleepers	0.98
	Kilogrammes.
Weight of Martin steel rail supplied by the Firminy Company's iron and steel works—make of 1872	38.000
(The Company has besides employed Bessemer steel rails of	

the same section, supplied from the works of Terre-noir and Bességes.)

Chairs from the Marquise Works (Pas-de-Calais), made in 1869—weight of a chair..........	10.200
Spikes made at the Devaux Works at Vieux Condé (Nord) in 1872—weight of a spike..........	0.440
Keys supplied by M. Bastiat, of Dax (Landes), make of 1872—weight of a key..............	0.900
Fish-plates from the Alais Works, make of 1873—weight of a pair	9.100
Fish-bolts turned out from the works of M. Vankalck near Valenciennes, in 1873—weight of a bolt.......................	0.445
Brunel rail, cast of Bessemer steel for turntables, sent out from the works of Terre-Noir (Loire), make of 1870—weight of linear metre	34.500

NORTHERN RAILWAY COMPANY.

Section.—The Northern Company has adopted for its entire system a steel rail of the Vignoles section, weighing 30.300 kilogrammes per linear metre. This rail is supplied indifferently by all the French houses; at the present time it is rolled at the works of Terre-Noir and Creusot.

Length.—The normal length is 8 metres, but lengths of 7, 6, and 5 metres are admitted in the orders for the convenience of manufacturers.

Sleepers and fish-plates.—The rail is laid with sleepers at the joints, and intermediate sleepers at the following distances from centre to centre: 0.60 metre for those next to the joints, 0.90 metre between those next adjoining, and one metre for all others. The rails are joined one to the other by means of fish-plates, with four holes of .019 metre in diameter drilled for the fish-bolts. The rails bear directly on the sleepers, in grooves made for the purpose, and are fixed thereto by means of two galvanized-iron wood screws for the intermediate sleepers and four wood screws for those at the joints. The wood screws are screwed against the flange of the rail in such a manner as to avoid punching or notching it throughout its length.

The reasons which have determined the choice of this type of rail may be summed up as follows:

Advantages of the use of steel for rails.—The chief advantage which results from the use of steel rails in preference to those of iron is that the wear caused by friction is even, being parallel with the length, and takes place slowly, whereas the best iron rails deteriorate under the influence of the traffic, and are found to be for the most part unfit for use before they have lost any appreciable portion of their weight by even wear. The experiments made by the Northern Company on iron rails from all sources have demonstrated that the best samples upon their system have not withstood a traffic of more than twenty million tons, and that for those of ordinary quality this figure does not exceed fourteen millions. In the case of steel rails, all the trials made prove that the table of the rail wears away uniformly at the rate of one millimetre for every twenty million tons passing over it; and as the rails are got out with a view to their losing 10 millimetres by wear, it can be estimated that they will endure a traffic of at least 200 million tons; that is to say, that the endurance of the steel rails is more than ten times that of the iron. The substitution, therefore, of steel rails for those of iron effects a great reduction in the expense of maintenance, at the same time that it ensures a more even strength to the permanent way, and increases, in a high degree, the safety of working.

The second advantage in the use of steel rails over those of iron is, that they are rolled from a material of greater and more regular resistance than that possessed by the latter. The result of experiments made for the purpose of comparing the strength of the two materials is that, under pressure, the iron rails take an appreciable permanent set as soon as the compression and tension of the fibres reach from 17 to 18 kilogrammes per square millimetre, while in the case of steel rails this does not occur until the tension and compression exceed 38 kilogrammes. With direct tensile strains, the resistance to rupture of iron rails of good quality varies from 28 to 36 kilogrammes per square millimetre, while that of steel rails is between 65 and 75 kilogrammes. Lastly, when tested by a blow by means of the apparatus of the Lyons Railway, the iron rails did not present a mean resistance exceeding 400 kilogrammetres (2,893 foot-pounds), while that of the steel rails, of the section under notice, exceed 900 kilogrammetres (6,590 foot-pounds). The material of which the steel rails are composed can therefore be thus characterized: it affords a better guarantee of uniform texture, and its resistance to a tensile strain, and one by impact, is at least double that of the material of which iron rails are made.

The advantages gained by replacing iron rails by those of steel are therefore evident; a drawback certainly exists in the item of prime cost, but, in actual practice, by taking into consideration the difference of the resistance of the two materials, the weight of the steel rails can be reduced to 30 kilogrammes, still leaving them stronger than those of iron which they replace; thus not only reducing the excess of first cost, but also rendering the laying of them cheaper than that of iron rails.

Section.—The following are the conditions which the company has striven to attain, and which have led to the adoption of the form of rail shown by the section and by the sample accompanying this paper.

To preserve the same height as the iron rail of 37 kilogrammes, as well as the width and angle of the edges of the fish-plates and the curve of the head, which have given good results in practice.

To give as large a margin for wear as possible, and with this intention to increase the size of the head while reducing the thickness and breadth of the flange, as much as possible without rendering their manufacture difficult, and without making the height of the rail too great in proportion to the breadth of its flange.

In theory, at the period of its greatest wear, the section of the rail should be such that the resistance of the fibres that are most strained in the head and in the flange should be the same; this would, however, have led to the adoption of a flange a little too narrow and slender both for bearing on the sleepers and also for being rolled. In the section fixed upon, the tendency towards extension becomes equal to that of compression after a wear of 5 millimetres, but at that period the rail is not so far weakened as to render it unfit for use, and after a further wear of 5 millimetres its resistance is still greater than that of a new iron rail of 37 kilogrammes.

Stability of the Rail.—It is only in respect to the stability on its base that the new type of rail can be regarded as less secure than the old one. A measure of insecurity of this kind is caused by the proportion of the height to the base; for this proportion, which is $\frac{125}{105}$, or 1.19 in the iron rail of 37 kilogrammes, rises to 1.288 in the steel rail of 30 kilogrammes. But there is ground for remark in this place that in the iron rail of Vignoles section, employed by the Lyons Company, this proportion rises to 1.30, and in that of the Cologne and Minden line this proportion is 1.356. Besides, the rail has no tendency, as was thought at first, to be overturned towards the outside of the line of way under the lateral strains which it must undergo from the flanges of the wheels; its tendency is rather to be driven on one side, which, however, the wood screws on the outside, and the cant given to the rail by the groove in the sleeper, are sufficient to counteract. Another consequence of these thrusts is to increase the pressure of the flange of the rail upon the sleeper on that side against which the wheels press; but the experience acquired for more than two years during which this rail was in use on the Northern system proves conclusively that the greatest pressure of this kind does not exceed the limits which the sleepers can bear. It is, therefore, certain that a diminution of the lateral dimensions of the rail of primitive type, weighing 37 kilogrammes, still leaves the rail sufficiently stable as regards the flange.

Quality of the material.—The results of these calculations and experiments have reference to a quality of steel, characterized by a degree of hardness and strength before determined, which is readily made at the French works. This quality is determined by tests which are stipulated for in the conditions of the company, and of which the following is the resume:

1*st test* (*with pressure*).—Each rail, submitted to the trial, when placed upright on two points of support, distant from each other 1.10 metre, should be able to bear for five minutes, at the middle of the interval between the points of support:

1. A pressure of 17,000 kilogrammes, without taking an appreciable permanent set after the test;

2. A pressure of 30,000 kilogrammes, without the deflection exceeding 25 millimetres.

2*d test* (*by impact*).—Each of the two portions of rail which have been broken, placed in an upright position on two supports (distant from each other 1.10 metres) fixed on an anvil weighing 10,000 kilogrammes, must sustain, without breaking, the impact of a monkey of the weight of 300 kilogrammes falling from a height of 2.25 metres, on the middle of the distance between the points where the rail is supported.

When sustaining a blow from the successive heights of..........	1.00m.	1.50m.	2.00m.	2.25m.
The amount of bend caused should not exceed........	1mm.	3½mm.	8mm.	18 to 20mm.

Trial of a new system of laying.—At the present time a new system of laying the rails is being tried, which consists in arranging the joint so as to come on two sleepers near to one another instead of on the same sleeper.

Although this method has not been tried for a sufficient time to be judged by practical results, it is expected to allow of an easier motion than when the joint is made upon the same sleeper; in fact, as the shocks due to the passing of each pair of wheels are not simultaneous, their effect on the carriage is thereby lessened.

Further, the severity of each of the shocks is softened by the following circumstances:

1. The joint sleeper, instead of having a tendency to inclination at each end, is on the contrary kept in its proper position at one end by the pressure of the continuous rail which it supports.

2. The ballast is less disturbed, on account of the sleeper being shaken less violently.

3. If a joint should happen to yield on the passing of a wheel, the carriage bearing on the three other wheels is not free to follow the movement.

WESTERN COMPANY.

The Western Company makes use of steel rails on that portion of its system where the traffic is greatest. The rails hitherto laid have been supplied by the following French houses:—Niederbronn, Imphy, Creusot, Terre-Noire, Firminy, and Commentry; they have been manufactured by the Bessemer and Martin processes, and at first a small quantity was manufactured from steel cast at Creusot.

The length of a single line of way, laid with steel rails, was, on the 31st of December, 1872, as great as 234 kilometres.

With the exception of the rails of Vignoles section laid on the large iron bridges, the steel rails employed are of the double-headed section, the same as that of iron rails.

Their mean weight is 38.75 kilogrammes per linear metre, that is to say, 1 kilogramme heavier than the iron rails, which weigh 37.75 kilogrammes.

The rails are in lengths of 6 metres, and the joints are made out of perpendicular, with fish-plates, which are also made of steel.

The rails, 6 metres long, rest on eight sleepers, with chairs disposed at the following distances: From joint to centre of first chair, 30 centimetres; centres of first and second chairs, 70 centimetres; centres of all the rest, 80 centimetres.

The chairs, which are of cast iron, weigh 15 kilogrammes each, having a bearing surface of 482 square centimetres.

The chairs are fixed to the sleepers by two wood screws, except in the case of the outer rail on curves, where there are three wood screws to each chair, thereby causing a slight difference in its pattern.

Paris, Lyons, and Mediterranean Line.—Since the year 1867, the above company decided to use only steel rails in relaying its permanent way on 860 kilometres on the Paris and Marseilles line, where more than 10,000 trains ran over each line of way yearly, at speeds which might reach 90 kilometres per hour.

On the 1st January, 1873, the length of the portions relaid with steel rails was as great as 940 kilometres of single line of way.

Particulars of the Paris and Mediterranean rail.—The rail exhibited (Paris-Mediterranean model) weighs 38.850 kilogrammes per metre; the section differs only from that of the iron rail (Paris, Lyons, and Mediterranean) employed on all the new lines of the Mediterranean system by the thickness of the web being reduced from 16 to 14 milimetres, and by the breadth of the flange being increased from 100 to 130 milimetres.

The shape of the head and of the flange

being of the same inclination and distance apart in both sections, the same form of fish-plate can be used.

The standard length of the rail is 6 metres, and they are laid on eight intermediate sleepers, with the joints at a bevel.

Fish-plates.—Each joint is made by a pair of iron fish-plates, with four holes, bolted together by four 25-milimetre bolts, with two feathers. An iron pin, inserted in a hole formed half in the fish-plate and half in the nut, prevents the slackening of the latter.

Method of Fastening.—The rail is fixed to each sleeper:

1. On the inside of the rail, by a spike with two claws, driven into a hole punched in the flange of the rail, to counteract any tendency in the rail to slide in the direction of its length or to heave over on its side.

2. On the outside of the rail by a dog.

Manufacture. — The Paris-Mediterranean rails are manufactured in the works of Creusot, Terre-Noire, and Besseges, either in Bessemer or Martin steel. If made by either process, the rails easily stand the tests below detailed; the results do not differ materially; but from some establishments the Martin steel appears a little harder of the two, while in others the advantage is with the Bessemer steel.

Tests.—One per cent. of the rails manufactured are submitted, on delivery, to the following tests:

1. Each bar, placed upright on two points of support, a metre apart, must bear, for five minutes, on the middle of the distance between the points of support, a pressure of 25 tons, without taking any appreciable permanent set.

2. The same bar, in the same position, must bear for five minutes, without exhibiting signs of fracture, a load of 40 tons; the load is then gradually increased until the rail is fractured.

3. Each of the portions of the bar, laid on two points of support, 1.10 metres from each other, must bear, without breaking, the impact of a monkey of 300 kilogrammes' weight falling from a height of 2 metres on the middle of the space.

4. A length of 70 centimetres is taken at pleasure out of each pour of the metal; it must bear, without fracture, when placed on two supports, 50 centimetres apart, the blow of a monkey 300 kilogrammes in weight, falling from a height of 1½ metre.

Results given by Steel.—The expectations formed in the year 1867 on the endurance of the metal are now fully confirmed by practical results.

No signs of giving out are observed in the rails that have been laid down more than five years ago, a uniform wear only being manifested, which bears witness to the perfect homogeneousness of the metal.

Several portions of permanent way laid down for trial have been examined after 40,000 trains have passed over them. The wear returned is eight-tenths of a milimetre (0.0008 metres) measured vertically, or a milimetre for every 50,000 trains. As the table of the Paris-Mediterranean rail can, without being unduly weakened, be pared or worn away uniformly to the extent of 10 milimetres and more, the supposition is warranted that it would require the passing of 500,000 trains to render the rails unfit for use.

To allow a margin for accidents and chances of error, if we take 400,000 trains as the maximum of traffic, and if, on the other hand, the mean endurance of iron rails, under the same conditions, is taken at 80,000 trains, the conclusion will be arrived at that steel rails may be considered as capable of enduring at least five times as long as those of iron.

Broken Rails.—The average number of rails broken in use which have to be taken up from the permanent way, is one rail per 15 kilometres of way per annum. Inasmuch as fractures occur for the most part soon after the first laying of the rails, they can most frequently be attributed to flaws in manufacture. The steel rails, when they have stood some months, may be considered as secure from all accident. In fact, it may be said that they will never break.

Net Cost.—One kilometre of Paris-Mediterranean permanent way costs:

1*st.* *With Steel at* 280 *fr. per Ton.* (*Price in September*, 1869.)

	Fr. c.
77,700 kilogrammes of rails..........	21,656 00
666 fish-plates (weight: 5.30 kilogrammes) at 180 fr. per ton.............	635 36
1332 fish-bolts (weight: 0.70 kilogrammes) at 350 fr. per ton............	326 34
2664 spikes (weight: 0.41 kilogrammes) at 275 fr. per ton.............	300 76

2664 dogs (weight: 0.39 kilogrammes) at 275 fr. per ton	285	70
Total	23,204	16

2*d*. *With Steel at* 400 *fr. per Ton.* (*Price in January*, 1873.)

	Fr.	c.
77,700 kilogrammes of rails	31,080	00
666 fish-plates at 340 fr. per ton	1,200	13
1332 fish-bolts at 500 " " "	466	20
2664 spikes at 445 " " "	486	04
2664 dogs at 445 " " "	462	83
Totals	33,695	20
	23,204	16
Increase of value in 1873	10,491	04

The samples exhibited are sent out from the works as follows: A Bessemer steel bar $1\frac{1}{2}$ metre long, of the Paris-Mediterranean section, showing one of its ends fractured, from the Creusot Works; a Bessemer steel bar, 750 milimetres long, of the Paris-Mediterranean section, and also a Martin steel bar of the same section, showing fracture at one end, with fish-plates bolted to it at the other, from the Besseges works.

The fish-plates are manufactured at the Ancy-le-Franc Works, and the fish-bolts, as well as the dogs and spikes, at the establishment of the widow Loiseau, Paris.

Orleans Company.

The Orleans Company make use of steel rails on those portions of its system where the traffic is the heaviest.

These rails, whether made by the Bessemer or the Martin process, are supplied by the different French companies, who have put up the plan necessary to these processes; for instance, Imphy, Creusot, Terre-Noire, Firminy, and Commentry.

With few exceptions, the steel rails in use on the Orleans system are all double-headed, and their section does not differ from that of ordinary rails.

The weight of the steel rail is, on account of the different density of the two metals, a little greater than that of the iron rail (which is 36 kilogrammes per linear metre) and can be reckoned at 37 kilogrammes on an average.

The rails are $5\frac{1}{2}$ metres long. They are jointed on the bevel with fish-plates, and rest on cast iron chairs, which are spiked to six oak sleepers, thereby giving a distance between centres of the latter of $\frac{5.50^{m.}}{6}$ or 916 milimetres.

The chairs weigh $9\frac{1}{2}$ kilogrammes, and have a bearing surface of 324 square centimetres.

QUEEN ANNE STYLE OF ARCHITECTURE.

From "The Architect."

It is to be hoped that a certain class of our more youthful and enterprising architects are falling in with the right kind of examples just now, for it may be taken as quite certain that they are attentively studying in one way or another during these holidays what "Queen Anne" work they can do. Not that they will be able to discover much of it that is at once genuine to the title in its conditions and satisfactory to the taste in its character; but this is no matter. The so-called "Queen Anne Style," as has been pointed out in this journal before, is not necessarily a fashion of the days of Queen Anne, or even an English fashion at all. It may probably be best described as a somewhat fanciful and indefinite mode, of general rather than special characteristics; the result of a vague desire for change, rather than a distinct impulse of revival; and embracing within its limits the widest extent of diversity of treatment, in order to suit whatever may be the unanticipated necessities of an individual designer at the moment, rather than confining itself within archæological, æsthetic, or academical bounds of any kind. *Free Classic*, in short, the term applied to it alternatively by one of its most earnest advocates, Mr. Stevenson, at the recent Architectural Conference, may be said to indicate expressly, better perhaps than any other formula of words which could be used at the present moment, the peculiar pretensions of the movement: it professes to be Classic—no matter how—as a question of change from the popular Gothic; and it claims to be Free, as an assertion of artistic independence such as shall repudiate all trammels of either dogmatic or conventional method. The Queen Anne Style may be said to be in reality very much whatever its votaries shall find it convenient to make it; the only conditions which seem to be recognized are that it shall be a revolution from the Gothic in principle of design, and a rival to the Gothic in freedom of treatment. To put the case in still another form, we may suggest that true Classic, true Gothic and "Queen Anne" are looked upon in this relation; our true Classic, of the early part of the present century, was a style of mere book-learning—a dead language; our true Gothic, of the last five-and-twenty years, has been free and adventurous to the utmost; this having had its innings, it has come to be the turn of the other; but let not the other play on its old prosaic system—let it adopt a new one—let it take a lesson from its opponent and be free and adventurous too.

If anything like this view of the matter can be accepted by the reader, he will scarcely fail to perceive the probability that the resumption of architectural enterprise after the present recess will bring with it a good deal of endeavor towards the ascertainment, as we may express it, or definitive settlement, of the new mode; in which, it may also be considered probable, foreign examples of design will be held entitled to share with English the credit of furnishing material from the past. German work, Flemish and Dutch work, and perhaps especially French work, of the sixteenth and seventeeth centuries, may be expected indeed to take the lead of English altogether, for two simple and obvious reasons. In the first place there is far too little Queen Anne work in England—however comprehensively the title may be applied—for the formation of a revived or even a novel style of any vigor or stateliness; and, in the second place, during the last twenty years it has been one of the most remarkable conditions of English architectural study that the chief part of its material has been derived from abroad. In other words, if a new mode is to be established by English adventurers, they may unquestionably be expected to go to the Continent for their principal studies; and it is on the Continent alone, and not in England, that examples are to be found of the desired character, such as may be relied upon for guidance and suggestion. The particular manner of design which Mr. Stevenson seemed to have in his mind as the type of the proposed new style was that of the red brick houses, and the yellow (or whatever color it may be), with red quoins, having flush or nearly flush broad window frames painted white; of which mode we see a vast number of examples in various parts of London and the old suburbs, and in a great many of such provincial towns as stand in a brick country. There is also a large amount of similar work in country houses, and in office buildings of various kinds, and occasionally in public edifices of no great importance. It is obvious, however, that to confine the student's attention to this class of examples would be to limit the scope of the new movement to the production of a kind of scarcely quaint and certainly weak domestic design, out of which it would be altogether impossible to construct anything approaching to the dignity of a national mode. It might answer very well for plain houses, and for certain classes of unambitious municipal buildings, but for great metropolitan edifices, for grandiose streets, and for the whole category of monumental works, its adoption would be almost a caricature. Nor does it mend the matter if we include the kindred mode of half timber work; for it is plain that the field of usefulness of this primitive kind of construction must be very small indeed, except perhaps in country houses of a small and cheap kind. Beyond the limits of these two modes, the style of work in question can scarcely be said to extend in England. But on the continent, where, at the date of such work, architectural art, almost obsolete in England, was flourishing almost luxuriantly, such of our tourists as are disposed to worship a rising sun by offering homage to the "Queen Anne Style" cannot fail, if sufficiently intelligent and sufficiently liberal in their views, to discover almost any amount they may desire of such specimens of architectural design as are certainly not Gothic and still emphatically picturesque. All this, as we understand the case, will be thankfully accepted by the promoters of "Free Classic;" and out of the mass of material thus to be acquired, as we venture to suppose, the alphabet of the new architectural tongue has really to be formed.

It is by no means evident yet that this

course, or whatever like process may be adopted, will be either a success or a failure. The basis of the new adventure is the assumption that our modern Gothic —except, we suppose, in ecclesiastical work—is worn out, or so very nearly so, as to be but holding office till its successor is appointed. This is of course denied stoutly enough; but, at the same time, if successful competition designs are to be looked upon, as they generally are, as the shadows of coming events of change, we are scarcely able to ignore the fact that several of these have lately gone strongly in the direction of the style we have described. All we would wish to say, however, is this:—If the revolution is really to be effected, we hope it will be directed by its leaders into such a line as may do themselves and their art some credit. Even if the coming mode is to be, as has been suggested, no more than a stepping stone to something better—that is to say more academically appreciable—still we would hope that it may be worthy of attention while it lasts. As regards this, much will depend, we are disposed to think, upon the proceedings of the present recess, leading up to the course which is to be taken in competition and other works on the resumption of business; and one thing that we may venture to say is that, whether our next year's fashion is to be a continuation of Secular Gothic, or a temporary reference to "Queen Anne," or a more direct revival in some sort of Classic of a less "free" type, English architecture of the non-ecclesiastical class can scarcely afford to fall into any greater confusion than at present prevails.

THE NARROW-GAUGE RAILWAYS OF EUROPE.

By A. Stevart.*

From "The Universal Review of Mining."

This work dates from the end of 1871; the questions treated therein were then the order of the day amongst all the engineers in the world, and have lost none of their interest up to the present time.

We shall confine ourselves strictly to European narrow-guage railways, on which the traction takes place on rails by locomotives of ordinary adhesion, in a manner analogous to, and, consequently, comparable with that of broad gauge-lines.

We shall say nothing about the mountain railways, such as that of Rigi, and those on the systems of Fell and Wettly; neither shall we direct our attention to the lines of single rail on the system of Larmanjat, and others, nor of suspended railways like those of Brighton and Ceylon, on Hodgson's system.

These are all schemes to be judged from one specimen, whereas narrow gauge lines having been in work a long time, can be compared directly with ordinary lines.

We may consult with advantage on this subject:—

In French. Level: "Construction and Working of Railways of local interest." Paris, 1870. "Memorials and Reports of the meetings of the Society of French Civil Engineers, 1868-1869." Loisel: "Special-year book of Belgian Railways." Brussels, 1867-69. Statistical information published by the Belgian minister of public works.

In English. *The Engineer* and *Engineering*, 1869 to date. Discussions and voluminous correspondence on narrow gauge. Rob. Fairlie; "The Gauge for the Railways of the future."—Paper on "Railway Gauges," read before the British Association at Edinburgh, 1871. —"The Battle of the Gauges," London, 1872. Spooner: "Narrow Gauge Railways."

In German. The very important memorial of the technical commission, appointed by the union of the German railways; "Grundzuge fur die Gestaltung der secundaren Bahnen." (Organ fur die Fortschritte des Eisenbahnwesens, 1869.)

In Italian. Felice Biglia: "Sulle Ferrovie Economiche Due Relazione al Min-

* Memorial read before the Brussels section of the Association of Engineers, belonging to the Liége Academy.

istero dei Lavori Publici." (On Economical Railways, two Reports to the Minister of Public Works.) "Giornale del Genio Civile," 1870-1871.

Historical.

It is well known that the point of departure from the ordinary width of Stephenson's gauge (4 ft. 8 1-2 in. or 1.435 metre between the rails, or about 1.50 metre) 4 ft. 11.05618 in.) from axis to axis of the latter, was only the usual distance of the wheels of the carriages which the wagons were intended to replace.

This width of gauge, the most universally adopted, has, then, no really rational existence.

Once established, its adoption for English lines was inevitable, in consequence of the necessity of making them agree with the railways already marked out, and it afterwards became general all over the Continent, in imitation of what had been done in England.

In Belgium and France, 1.50 metre (4 ft. 11.05618 in.) was the distance from axis to axis of the rails, which gives a variable distance of 1.430 metres (4 ft. 8.3 in.) to 1.45 metre (4 ft. 9.0876 in.) according to the width of the flanges of the rails.

In Germany the Union Railway adheres now to the English gauge of 1.435 metre (4 ft. 8 1-2 in.)

Here and there, there was a departure from this rule, to increase it: thus the great engineer, Brunel, constructed the line of the Great Western Railway at a width of 7 ft., but the company was soon compelled, at great expense, to put down another rail to enable them to take in the traffic of the other railways; and, in consequence of inconveniences of all kinds occasioned thereby, it was decided, in 1869, to return to the normal gauge.

The Baden Railway, in Germany, has been constructed on the standard of 1.60 metre (5 ft. 2.99326 in.) and that of Amsterdam—the Hague-Rotterdam, in Holland—of 1.93 metre (6 ft. 3.98562 in.), but all those have returned to the ordinary gauge.

There are now four countries in Europe having a wider gauge than 1.50 metre (4 ft. 11.0561 in.), which have been adopted for political or strategic motives; these are:—Spain and Portugal, 1.68 metre (5 ft. 6.14292 in.); Russia, 1.525 metre (5 ft.); and Ireland, 1.60 metre (5ft. 2.99326 in.)

Out of Europe, the cradle of railways, we find all sorts of gauges.

In the United States, that of 1.435 metre (4 ft. 8.49708 in.) has prevailed, but there are several others, up to 1.83 metre (6 ft. 0.04854 in.)

In the English possessions of India, the gauge is 1.68 metre (5 ft. 6.14292 in.)

In Australia and Brazil, it is 1.60 metre (5 ft. 2.993 in.)

Lately, a revolution has taken place in all minds. We have seen, from numerous examples, that railways of broad gauge have been constructed at great expense in countries where the traffic was far from being remunerative, and in presence of this fact, that *all the elements* which go to establish the net cost of carriage—cost of construction and maintenance of the line, cost, and wear and tear of the rolling stock, working expenses, &c.,—vary in one way or another, with the width of gauge, it is only rational that we should apply ourselves to the consideration of the most suitable gauges for railways.

Animated discussions have been raised, especially in England, on the subject of the narrow gauge, and, to our mind, *the battle of the gauges* is not yet decided. Too many warm partisans have entered the lists, who are so positive in their ideas, that it is impossible to come to an agreement.

The question is complicated by too many conflicting elements, for a clear idea of the whole subject to bring about, all at once, a radical solution.

It is only by the light of facts that special cases can be resolved, when they arise; but we do not think it will ever be possible to decide dogmatically, and in a general way, between the comparative merits of the broad and narrow gauges.

What are the facts, then, on which an infallible judgment may be founded? They are already in existence in great numbers, in Europe, and we will produce them in the first part of this work.

In the first place, there are the Belgian lines of High and Low Flenu (1836), and from Antwerp to Ghent (1846); of which little mention is made, as is the case with every thing that takes place in our little modest country.

It is the same with the lines of Norway and Brœllthal (1862).

But, recently, a great noise has been made about an English line, of very narrow gauge, which has been a long time at work between Festiniog and Port-Madoc, in Wales, but on which locomotives have only run since 1863-'4.

The results put forward by Mr. Spooner, the directing engineer of the line, and warmly defended by Rob. Fairlie, have intensified the dispute.

As a consequence of these animated discussions, which will certainly tend to throw a new light on the technicality of railways, public attention has been drawn to the lines of this sort already constructed, and several experiments have been undertaken.

The Russian Government especially, on the presentation of the report of a commission appointed to examine the Festiniog Railroad, has constructed a number of lines of narrow gauge.

Out of Europe, the system is being tried in America on a grand scale, and the question is being debated as to whether a narrow gauge is to be employed for the extension of the net of Anglo-Indian railways, and for the construction through Persia and Asia Minor, of an immense line, which is to unite this country to Europe.

I. *Results obtained on Lines of small Section, in Europe.*

We shall devote a few lines to each of the principal reduced gauges, in Europe.

Not to go beyond the scope of this work, we shall abstain from all useless detail, in estimating the whole of the conditions of the establishment and the working of railways.

Having done this, we shall present in a general summary, the salient figures belonging to this part of our subject, so that the reader may be enabled, at a single glance, to compare them one with another.

1. *Railway System of High and Low Flenu (Hainaut), Belgium.*

Constructed and worked since 1836, in great part on a gauge of 1.20 metre (3 ft. 11.24494 in.), the rest 1.50 metre (4 ft. 11.05618 in.), this railway is not *a line* like the others of which we shall have to speak; it is a complete net, within which and a canal of great width (Mons, at Conde), it is intended to bring together all the coal mines, and industrial establishments of Flenu. Its total length is 92 kils. (nearly 58 English miles), about two-thirds of which consist of levellings in the vicinity of the coal mines, which are so numerous there. On certain sections this railway has two, three, and even four lines. The traffic is so enormous, that the gross receipts amount to nearly 1½ million of francs (£60,000). The average ascent is 10 millimetres (0.3937079 in.), and the maximum 0.025 metre. The curves descend to a radius of 30 metres (32 4-5 yards.)

The lines comprise rails of 28, 33, and 35 kils. (61¾, 72¾, and 77 lbs.) per current metre.

The traction has been done by the company (by the Belgian state since the 1st January, 1871), but the rolling stock is furnished by the coal mines, or by the adjacent railways for the wide line. The result is a great diversity in the rolling stock, which has been provided rather with a view of facilitating the service of the coal mines, than with that of the good management of the lines.

The wagons weigh, on an average, 2,000 kils. (nearly 2 tons) for a quantity of 24 to 40 hectolitres of coal, 2,200 to 3,600 kils. (46 to 70¾ cwts.), which forms a considerable weight. The transfer of the coal from these wagons to those of the wide line costs 20 centimes per ton.

The four-wheeled coupled locomotives, which do the service of the narrow way, weigh, on an average, 15 to 18 tons, in going order.

The working of this network, which cost altogether 71,000 fr. (£2,840) per kilometre, has resulted in a dividend of 10½ per cent. This brilliant result is to be attributed not only to the conditions under which the system was established, but also to the tariffs, which were the highest in the country.

This system of railways, which is more or less complicated in its lines of 1.50 metre (4 ft. 11.06518 in.) of gauge, is now worked by the state, and it is very likely that the lines of Flenu will be altered to the same width. The active traffic in coal at this point would justify the preference to be given here to the wide gauge.

2.—*Antwerp to Ghent, Railway of the Pays de Waes (Belgium).*

This railway, conceded, in 1843, after public auction, was constructed in 1844-'5, and was in full working condition in 1847.

Traversing in its entire length, 50 kils. (over 31 miles), the richest agricultural district of Belgium, it terminates in one part at the shore of the Escaut, facing the town of Antwerp, and serves for the crossing of the river in correspondence with the trains by means of steamboats for passengers, and sailing boats for merchandise.

At the other end, it terminates at Ghent, where it has a *terminus* station different from that of the state. It meets on its way two wide gauge lines, which it crosses.

At Lockeren, where there is a station belonging to the state, we meet with an example of the transfer of merchandise. The wagons of the two lines may be brought side by side or be placed one after the other on a line of double rails, and although the operation is nearly always performed by hand, or with the shovel, except for heavy articles, which are drawn up with a crane, the cost of transfer under these conditions does not, on an average, exceed 30 centimes per ton.

As the country presents very few inequalities, the line is everywhere nearly level. There are 8,500 metres (5.258 miles) of insensible slope (0.002 to 0.0035), and 530 metres (nearly 580 yards), with a slope of 0.006. On the whole line, the curves have a radius of 2,000 metres (1.304 mile), and one goes down to 800 metres (875 yards).

The only work of art on this line is a bridge across the small river Durme.

The distance from axle to axle of the rails is 1.15 metre (3 ft. 9.276 in.) These rails, which at first weighed 22 kilogs. (48½ lbs.) per current metre, have been replaced by others of 25 kils. (55 lbs.) on the Vignoles model. The sleepers are made of the oak grown in the country, or in fir from the North, done over with creosote.

Under these conditions the first cost of the line was 4,700,000 fr. (£188,000), including the rolling stock; or 94,000 fr. (£3,760) per kilometre (1093.633 yards). This amount has been increased from time to time by extensions and additions to stock; it reached 105,000 fr. per kilometre at the end of 1870.

The locomotives and rolling stock are well cared for, from an economical point of view. All honor to the engineer, De Ridder, one of the founders of Belgian railways.

As the company makes its own carriages and wagons, it employs the choicest material, and takes care to have them of the best workmanship.

If we take into account how long a rolling stock lasts when made under these conditions, and the small cost of its maintenance, it will be seen that this economy largely compensates for the greater outlay at first.

All the locomotives are of one type, with three axles, and independent wheels. The driving wheels are 1.40 metre (55.11910 in.) in diameter. Their fire-boxes were at first in iron, but they have all been replaced by copper ones, which last ten times longer. On the other hand, as regards the fire-tubes, better results have been obtained from iron (homogeneous metal) than from copper.

The engines carry 600 kilog. (about 12 cwt.) of fuel, and a reservoir of 2,000 kilog. (about two tons) of feeding water, on the boiler. They weigh, in going order, 16,450 kilog. (above 16 tons).

The rolling stock, which is very low on the wheels, notwithstanding their large diameter, is very original in its arrangements.

The passenger carriages have the same width as on the wide gauge lines, and the express trains run at the rate of 60 kilom. (37½ miles) an hour.

The luggage wagons weigh two tons, and carry a weight of five tons. The flat wagons only weigh 1,700 kil. (33½ cwts.), or one-third of the weight they carry.

Notwithstanding the isolated position of this line, it is worked very advantageously, seeing that, after deducting from the profits the sums necessary for renewing and increasing the rolling stock, the company, during the last few years, has paid a dividend of 7 per cent.

In spite of this prosperity, they contemplate increasing the gauge to 1.50 metre (4 ft. 11.05618 in.), and consequently to modify the rolling stock. But the considerations entering into this transformation have nothing to do with the arguments for or against the narrow gauge.

There are also in Belgium other railways of narrow gauge, but they are of so little importance that we shall not stop to discuss them.

We shall instance only the expense of transferring the coal on the Hornu line (0.90 metre), which amounts to 3 centimes per hectolitre ($2\frac{3}{4}$ bushels).

On another, at a gauge of 0.6 metre (1 ft. 11.622 in.), used for agricultural purposes (Chassart to Marbais), the transfer of the material of divers kinds is performed by the piece, at the rate of 15 centimes per ton, and never amounts to more than from 18 to 21 centimes per ton.

These prices may be regarded as a criterion of the cost of transfer from one set of wagons to another, *in the absence of any special facilities.*

3.—*Commentry to Montlucon (Allier), France.*

This line, intended to join the important mines and iron works to the wide line of the Orleans Company, and to the Berry Canal, was constructed in 1844, on a gauge of one metre (39.37079 in.) to be worked by horses. Now it is done by locomotives weighing 15 tons. Its length is 17 kilom. (nearly 11 miles). We find there curves having a radius of 90 metres, with a slope of one centimetre. The strongest inclination is 0.045 (1.7716 in.)

The rails weigh 18 kilog. (39.68 lbs.) per metre.

The wagons, which are of the simplest construction, deserve mention on account of their low price.

	Fr.
The coal wagons cost	500
Those with a brake cost from 700 fr. to	800
Flat wagons, only	250

The line has cost on the average nearly 110,000 fr. per kilometre.

4.—*Pontsericourt-service. Department de l'Aisne (France).*

This railway consists of two lines, constructed solely with a view to the sugar manufactory of Tavaux.

The line from Tavaux to Gronard, 8,500 metres (5.284 miles) long, is built on the side-space of a very uneven road. It presents a succession of rises and falls, of 15 to 25 milimetres, and afterwards, in traversing a chain of hills, ascents of 75 to 78, and 60 milimetres, the latter with a curve of 50 metres radius. The minimum radius of the curves is 30 metres.

The line from Tavaux to Moranzy, which is less uneven, has from 10 to 15 rises, some of them as short as 30 milimetres. On the other hand, over a length of 4,200 metres ($2\frac{3}{4}$ miles) through bad rural roads, there are several curves of 30 metres to 45 metres (98 ft. 5.124 in. to 147 ft. 7.685 in.).

Both these have a distance of one metre from axis to axis of the rails. The rails weigh 13 kilog. (28.66 lbs.); they are 6 m. long, and are laid on eight oak sleepers, one at each end.

The four-wheel locomotives, coupled, weigh 7,500 kil. (147 cwts. $2\frac{1}{2}$ qrs.), and are consequently wanting in adhesion; on difficult ascents they only draw one wagon.

The wagons, which are well adapted to their special use, which consists exclusively in the transport of beetroot, pulp, &c., weigh 2,100 kil. (2 tons), and will carry 6 tons.

The cost per kilometre (1,094 yards), is only 28,000 fr., 11,655 fr. of which sum was for rolling stock.

This line, then, was constructed at the extremely low cost of 16,335 fr.; but the engineers who have projected it affirm that it is one of the worst for working, and that they were compelled to make it what it is for want of time.

Nevertheless, the profit which these lines realize is estimated at 6 per cent. on the capital employed.

5.—*Festiniog to Portmadoc (Wales), England.*

This railway has existed since 1832, but locomotives have been employed on it only since 1863, the date at which Mr. Spooner introduced passenger traffic. Constructed in an uneven country, the object is to convey to the sea, at Portmadoc, the produce of the slate quarries of Festiniog.

It is 23 kilometres long (15 miles), has numerous curves from 35 metres of radius, average falls of 0.011, considerable embankments, and two tunnels in solid rock.

We may instance, as a characteristic of this line, that it is no rare thing to see a train winding on three curves at once.

The rails are placed at a gauge of 0.61 metre (2 feet); the first weighed 19 kil. (41.8 lbs.), and have been replaced by others of 25 kil. (55 lbs.).

The cost of construction amounted to

about 90,000 fr. (£3,600) per kilometre (1,093.633 yards), to which must be added 24,000 fr. (£960) for rolling stock, which brings the cost per kilometre up to 114,000 fr. (£4,560).

The rolling stock is one of those which attracted most attention.

The locomotives are of the sort which Mr. Robert Fairlie has again brought into use, for the system is only a reproduction of the Seraing locomotive, constructed in Belgium in 1849, for the Semmering competition.

These engines are in two parts, joined together, and have four coupled wheels of 0.712 metre, and draw at a speed of 18 to 32 kilometres (11 to 20 miles) an hour; trains weighing 75 tons to 107 tons.

They weigh 19,500 kil. (19.195 tons), and cost 50 per cent. more than ordinary engines of the same weight.

The rolling stock for goods is remarkable for its lightness, as compared with the load it carries. The wagons weigh on an average 18 cwt., and carry from $2\frac{1}{2}$ to 3 tons. The slate wagons, which form nine-tenths of the rolling stock, weigh only from 650 kil. to 850 kil. (from about 13 cwt. to 17 cwt.), and carry from two to three tons. These figures are the best arguments that can be adduced in favor of the narrow gauge.

The line yields a net revenue of $12\frac{1}{2}$ per cent. on the capital employed.

6.—Other slate quarries in Wales have followed the example of Festiniog; the Tallylyn line, for instance, 12,800 metres long (nearly 8 miles), gauge 0.68 metre, with maximum ascents of 15 milimetres; and the Dinorwic line, only 0.58 metre wide, with sharp curves, and worked by very small locomotives.

7.—*Brœllthal Railway, Germany (Rhenish Prussia).*

This line, 0.785 metre (2 ft. 6.906 in.) wide, was constructed nine years since, to convey the mineral products from the valley of the Brœll to that of the Sieg, where the wide-gauge line passes, from Cologne to Giessen. It joins this line at the Hennef station.

As, for a considerable part of its length, it uses the side-space of an adjacent way, it presents a certain number of curves of 38 metres radius, and inclinations of 125 milimetres per metre.

The rails weigh from 10 kil. to 13 kil. per metre.

The two locomotive engines, which perform the traction, have three axles, coupled, and wheels of 0.70 metre. They weigh fully 12,500 kilog. ($12\frac{1}{4}$ tons).

The wagons, which are of good shape for a railway of this kind, are, unfortunately, rather heavy; they weigh $2\frac{1}{2}$ tons, and carry a net weight of 5 tons.

As an important fact, we may remark that the tonnage is greater on a descent than on a rise. On a rise it is 13 per cent.; on a descent, 87 per cent.

The line cost 558,000 fr. (£22,320); or 25,250 fr. per kilometre, including 4,250 fr. for rolling stock.

The account of the company closed some years since with a net profit of 36,700 fr., or more than $6\frac{1}{2}$ per cent.; but this result has not been maintained.

8.—*San Leone Line (Sardinia).*

Constructed in 1865, for the purpose of conveying to the sea the produce of the iron mines, this line of 15 kilometres (nearly 10 miles) long, and 0.80 metre (2 ft. 7.497 in.) wide, presents a maximum slope of 4 centimetres per metre.

The sharpest curves have a radius of 45 metres (49 yds. 7.685 in.).

The locomotives being only $6\frac{1}{2}$ tons in weight, have permitted the use of rails of 13 kil. (about $28\frac{1}{2}$ lbs.) per current metre.

The wagons weigh 1,400 kilog. ($27\frac{1}{2}$ cwts.), and carry loads varying from double to treble.

This railway having ceased to work, in consequence of the mines which maintained it having become unproductive, we have no data either respecting the working or the profits made.

9.—*Monteponi Line (Sardinia).*

This line, 14 kilometres long, has slopes of $2\frac{1}{2}$ centimetres per metre, and curves of 100 metres radius.

The distance of the rails from axle to axle is one metre, and the rails weigh 20 kil. per metre.

Also constructed in a hilly country, to convey the products of the mines towards the sea, this railway cost 59,000 fr. per kilometre.

The rolling stock, which is estimated at 11,000 fr., brings the total cost to 70,000 fr. (£2,800).

The six-wheel locomotives of 0.75

metre, coupled, weigh 16 tons, and the wagons are very remarkable; for, although made of iron, and covered, they only weigh *two* tons, and carry a load of *five.*

Lines of Norway.

10.—*Hamar Elverum.*
11.—*Trondhjem-Stœren.*
12.—*Dramman Ransfjord.*

These three lines, so often referred to since the question of the narrow gauge was raised, include respectively, lengths of 39, 48.6, and 90 kilometres, with a maximum slope of 12, 23, and 17 milimetres per metre. The radius of the curves goes as low as 270 metres, and in the second even to 225 metres. The distance of the rails, which weigh 18 kil. per current metre, is 1.067 metre (3 ft. 6 in.). The locomotives weigh 17 tons, and have four coupled wheels and two hinder wheels. The driving wheels carry 13 tons.

The wagons weigh, on an average, 3 tons for a load of 5 tons; a considerable dead weight.

The cost of construction per kilometre was, for the first, 49,100 fr., 6,800 fr. of which was for rolling stock; for the second, 83,333 fr.,* 5,088 fr. of which was for rolling stock; and for the third, 70,424 fr., including 6,160 fr. for rolling stock.

The first two of these lines, opened in 1862 and 1864, had only yielded an insignificant profit in 1866, the date on which the third was opened.

13.—*Bœras-Uddevalla* (*Sweden*).

This line was partly worked in 1866, and was finished in 1867.

It is 131 kil. (81.401 miles) in length, of 1.20 metre gauge (over 47 in.), and in a country which is so comparatively level, that the slopes do not exceed 0.0166 metre, and the radius of the curves is not more than 300 metres; nevertheless the results have not been brillant.

Although the cost of construction, including the rolling stock, did not amount to more than 71,790 fr. per kilometre, it has only yielded a dividend of 1-2 per cent. on the capital.

* The land was very uneven; the excavations and embankments are considerable, and there are no less than ten bridges, three of which are very long and very high.

The locomotives have six wheels, four of which are coupled.

The rails weigh 22.5 kil. (49.604 lbs.) per current metre.

Beyond this we have little information respecting this line. One important detail, however, we have, that is, that the transfer of goods from the wagons of narrow gauge to those of the wide gauge, by the side of which they can be placed, only costs 10 centimes per ton.

14.—*Uttenberg-Kaping* (*Sweden*).

This railway joins the Uttenberg ironworks, and the saw-mills of this district, to Lake Malar, and the wide-gauge lines. The construction of this line is one of the most economical that we know of.

Its total length is 36 kilometres (22.364 miles). It is made of rails of 18 kil., placed at a distance of 1.09 metre. The slopes do not exceed one centimetre per metre. The curves descend to 250 metres of radius, and the cost of construction was as follows:

	Fr.
Permanent way	25,713
Rolling Stock	4,372
Total cost	30,085 per kilometre.

The locomotives with four coupled wheels weigh 13 tons.

The goods wagons carry 6 tons, and weigh from 2 1-2 tons to 3 tons.

The working, commenced in 1866, produces a net profit of 4 1-2 per cent. on the above capital.

15.—*Vierhovie to Livny* (*Russia*).

At the commencement of 1870, the Russian Government appointed a commission, of which Count Bobrinsky was president, to examine the Festiniog line, and to report upon the results of its working.

The report of this commission, favorable to the narrow gauge, recommended that of 1.067 metre (3 ft. 6 in.), and the construction of 61,500 metres (57 1-2 versts) of that gauge was decided upon by the Imperial Government.

It was formed in a country attended with great difficulties of construction. In the middle of its length it crosses the river Limbovsha, over a viaduct 128 metres (140 yards) long, and 13.7 metres (45 ft.) high. At this point the level of the rails is 108 metres lower than at the extreme stations.

The strongest fall admitted is 1 in 80, or 0.0125; it goes over 8,850 metres (96. 79 yards) in one sense, and 6.440 metres (7,043 yards) in the other. The total of the declines comprised between 0.0125 and 0.01, extends over a total length of 23,400 metres (14 miles 951 yards).

There are 55 curves, the sharpest of which has a radius of 208 metres (227 1-2 yds.).

The bridges, which number 52, are all built of wood, in the Norwegian style: the largest is 154 metres (168 yds. 1 ft. 3 in.) long, and 24.40 metres (80 ft.) high.

The rails, laid on wooden sleepers, are 6.10 metres long, 0.102 metre high, and weigh 22.3 kilogrammes per current metre.

All the buildings are of wood, except the workshop and the locomotive house, which are of brick.

The rolling stock consists of two locomotive-tenders, weighing 17 tons, and five other locomotives, weighing 35 1-2 tons.

Seventeen passenger carriages, and 266 goods wagons, of which the relation which the net weight bears to the gross weight is very high, as will be seen from the following figures:

Flat wagons, relation of the weight to the tare	3.96
Open " " "	3.14
Closed " " "	2.66
Brake " " "	1.01

A train of fifty wagons weighs on an average 350 tons, 242 tons of which is net weight.

The construction of this line cost 95,000 fr. per kilometre (25,500 roubles per verst). Of this sum, 26,000 fr. is for stock.

It was opened in 1871, but nothing is yet known of its financial results.

16.—*Novgorod-Tchudowa* (*Russia*).

This line, of 1.067 metre-gauge (3 ft. 6 in.), and 73.2 kilometres (about 46 miles) in length, is constructed in a flat country, and is principally used for passenger traffic. Its engines are on the same principle as those used on other European railways.

For a net weight of 6 tons, the open wagons on this line weigh 2,200 kilogrammes (43 ¼ cwt.), and the closed ones 2,600 (51 cwt.)

The cost of construction amounts to 67,500 fr. (£2,700) per kilometre.

This railway is of little interest, as the traffic is principally for passengers. Besides, it is of too recent date for us to have any data respecting the result.

II.—*Advantages and Inconveniences of the Narrow Gauge.*

The advantages of the narrow gauge are insignificant, unless it be adapted with a view of being used for a large number of trains, composed of wagons lightly loaded, and drawn by light locomotives.

Railways of narrow gauge can have no pretension to cope with the requirements of a large and rapid traffic.

When we speak of trains heavily loaded, or swift express trains, we mean *a locomotive possessing a considerable fire-grate area, and of great stability*, things which are only obtained with difficulty with a gauge of 1.50 metre, and are radically irreconcilable with a reduced gauge, and a diminution of the radius of the curves.

In considering the question, then, we will take for granted—

1. That the traffic on lines will never require a greater speed than from 30 to 35 kilometres (20 to 23 miles) an hour, at the most. for passengers, and 20 to 25 kilometres (14 to 16 miles) for goods.

2. That the trains will be numerous, and relatively light.

These two conditions will admit of *a narrow way*, *with light rails*, *with curves of small radius*, *and strong slopes*, *light locomotives*, *short wagons*, *with the axles near to each other*, all, as we shall see, elements of real economy.

Thus put, the question will be divested of nearly all the objections generally urged, and we shall have little else to do than to speak of the advantages in its favor.

As far as we are concerned, we consider these conditions to be the exclusive property of railways of narrow gauge; and when once they are departed from, all the advantages turn against them, and become so many inconveniences.

A.—Construction of the Line.

1.—*The Land.*

The length and width of the land required diminish at once, so that for a narrow way there is a considerable saving in the purchase of the land.

The importance of this element will necessarily be in proportion to the value of the land in the district where the line has to be constructed.

2.—*Excavations and Embankments.*

(*a.*) *Lateral Sections.*—The reduction of these sections may become very considerable. We may regard it as approximatively proportionate to the difference in the width of the line, and the height of the excavation or embankment. It has nothing to do with the slope of the embankment.

(*b.*) *Longitudinal Sections.*—Here the economy is manifest. The length of the line diminishes considerably from the moment that the ascents and descents increase. Between two given points of altitude, all things being equal, the length of the line will be in inverse proportion to its average bias.

Besides, in proportion to the curves of small radius, the line can adapt itself more easily to the sinuosities of the ground, follow what the English call the *lines of surface*, and easily avoid considerable works of art.

3.— *Works of Art.*

A reduction of width will be of great value with respect to these, and especially where tunnels are necessary. As well as being reduced in number, their importance will also be diminished.

4.—*Laying down of the Line.*

(*a.*) *Ballast.*—The great reduction in the trunk of the line, and the diminution in the height of the ballast, which, in a narrow line, may fall as low as 12 or 15 centimetres, will ensure a considerable saving.

(*b.*) *Logs.*—The expense of blocks will be reduced in every way; they will be less in number, shorter and thinner.

(*c.*) *Rails and Accessories* —The wide lines now have rails of 36 to 38 kilogrammes (79 lbs. to 83 lbs)., per current metre; whilst narrow lines, as we have seen, have rails of 10, 13, 18, 20, 25, and, at the most, 28 kilogrammes per current metre, or a reduction on an average of 50 per cent. in rails.

In a word, as regards the construction of a line, the economy attending the adoption of the narrow gauge, with all the conditions of working which it implies, is very great.

The majority of European lines of wide gauge have cost, for the line alone, from £8,000 to 14,000 per kilometre (1,993.633 yards): and it must be admitted that it requires great care in laying out the line, and in considering such special conditions as the land, to keep below the amount of £6,000 per kilometre, when the line is a wide one. Now the European lines of wide gauge, according to where they are constructed, have cost from 16,000 fr. (£640) to 91,000 fr. (£3,640) per kilometre, and on an average £2,280.

When we look at these figures there is great reason to believe that a large amount of useless capital has been sunk in lines of wide gauge; and this ought to induce us to return to the construction of economical lines, wherever the traffic is capable of being developed, and where there is no hope of its soon increasing to such an extent as would justify the construction of lines of wide gauge.

B.—Rolling Stock and Traction.

1.—*Locomotives.*

In proportion as they are light, locomotives cost more, relatively to their power; but this is only a small expense compared to others, and we shall not stop to consider it. We have seen by the foregoing table, that the weights of the locomotives used in Europe, on reduced lines, vary from 15 to 18 tons.

By using an engine on Fairlie's system, the Vierhovie-Livny railway has been enabled to use a locomotive of 35 tons weight, on a line of 1.067 metre (42 in.).

This is a remarkable result, but it does not justify the opinion of Mr. Fairlie, that his locomotive is the indispensable auxiliary of the narrow guage.

There is here a practical question to solve in each case. In proportion to the traffic, what is the adhesion, and, consequently, the serviceable weight that engines should have?

This weight—can it be fixed at one, two, or three axles, without straining the rails? If it can, then engines such as Fairlie's ought to be avoided; if it cannot, it will be necessary to choose between those of Fairlie's system and others.

2.—*Passenger Carriages.*

Passenger carriages are very difficult to construct for the narrow gauge; as soon as it goes down to one metre, and less, the number of seats in a carriage is necessarily reduced.

But we calculate that the cases which require the construction of a line of narrow gauge are always those where second-class carriages may be used, and that the fare can be raised without causing any inconvenience.

3.—*Luggage Wagons.*

It is here where the question of the narrow gauge becomes most interesting. By making the wagons short and compact, we effect a great saving in the price, and the tonnage of these vehicles is not in the least diminished.

Let us consider this question more closely, and by the light of facts.

It is a rare thing to see, on large railways, good wagons (except flat ones), which weigh less than half the net weight which they have to carry.

Taking into account the locomotive, the tender, brake wagons, etc., we may say that in case of a good train *fully loaded*, the net weight can only be calculated at 60 per cent., the dead weight being at least 40 per cent.; the wagons may be ever so lightly loaded, or even empty; it may easily happen on large lines, that only *half the entire weight consists of goods*.

In a narrow-gauge line, the tonnage of the wagons will, doubtless, be reduced; but as we have already seen, it is easy to make a wagon solid enough to convey three times its own weight.

It is only in exceptional cases, where the goods are bulky, cumbersome, and light, that these advantages are lost. Generally speaking, with dense bodies such as the produce of quarries and mines, we arrive at the normal condition of the trains, where the dead weight of the wagons is only a quarter of the whole weight.

In support of this, we may also observe that a reduced tonnage is more easily compatible with full loads, than a high tonnage, for which a considerable traffic is an indispensable necessity.

It is not without reason, then, that the *reduction of the dead weight* has been made the war-horse of narrow-gauge lines.

On lines of wide gauge, we may say that the dead weight increases daily, in consequence of the requirements of the traffic.

The speed of the train, the rapid manœuvring, etc., require a rolling stock more and more solid, and, consequently, heavier and heavier.

These requirements are not felt on narrow gauge lines.

C.—Cost of Working.

The cost of working a line in full activity being in proportion to the number of trains which run upon it, it will be seen that we have two essential elements of reduction of the expenses in:

1. The reduction of the length of the line by the adoption of an economical plan.

2. The increase of the relation between the serviceable load and the dead weight which will diminish the number of trains for the same traffic.

We must also add, less wear and tear of the road; that is to say, making a better use of it, by running light locomotives, the wheels of which do not press with greater weight upon the rails than those of the wagons.

On large railways, the whole of the line is constructed with a view to locomotives, the axles of which are twice as heavily weighted as those of wagons. Thus, the construction of wagons which, when loaded, press as heavily on the rails as the heaviest locomotives, may be looked upon as one of the *desiderata* of our great traffic lines.

The wear and tear of the rails certainly form one of the largest items of expense in a railway, which can be reduced by adopting the narrow gauge.

As we have pointed out above, the cost of constructing the line and the price of the rolling stock being much less, the working will not be hampered as it is in large railways, by the necessity of paying the interest on the large capitals sunk. French engineers who have examined the question maintain that, for an economical line, a traffic of 60 to 80 tons per day is sufficiently remunerative.

The European reduced lines, with exception of the Scandinavian, which have not sufficient traffic, have produced financial results that the immense majority of lines of wide guage might envy.

We meet here an objection often urged against narrow-gauge lines, when they have to come in contact with those of wide gauge. This objection consists:

1. In the expense of transferring the goods from one set of wagons to another.

2. In the delay thereby occasioned.

3. In the damage done to the goods transferred.

4. In the necessity of furnishing the narrow-gauge line with wagons and tools as complete as if it were the only line in the world, seeing that it cannot borrow any of the material belonging to the wide-gauge lines.

These objections are of that kind which, instead of throwing light upon discussions, only envelop them in a fog; they confound what is general with what is only peculiar, and fall, at one and the same time, into those numerous cases where the reduced lines are isolated from the wide ones, as well as into those where the course of the line is towards seaports, rivers, or canals.

Each of them must be examined separately to appreciate their importance.

Thus, the cost of transferring goods, as we have shown carefully, in speaking of European lines described in this work, is 20, 18, 15, and even as low as 10 centimes per ton, according to the place.

There is no doubt that, by the adoption of mechanical contrivances, it may be done for the lowest figure we have quoted, whilst at the same time the rapidity with which the work may be done would be so increased as to remove altogether the second objection.

It is evident *a priori*, that a very small economy in working would suffice to cover the maximum charge mentioned above.

It will be sufficient, for example, if the adoption of the narrow gauge has shortened the line by a few kilometres, for the cost of transferring the goods will be more than counterbalanced.

We need not say that the means adopted for the transfer of merchandise ought to be used for every category of transports, to avoid damage; thus, there only remains the fourth objection, which also resolves itself in each particular case into a comparison between the cost of rolling stock and the importance of the traffic.

The great objection with respect to the reloading of goods is, therefore, a phantom, which vanishes, if we keep within the limits of any given data, and is easily appreciated when, in any particular case, it resolves itself into a question of francs and centimes.

It will be well to add to this chapter an important consideration respecting the way in which the traffic is generally distributed on lines of narrow gauge, when constructed in hilly countries. They have then strong slopes, which at first seem to increase considerably the cost of working, especially in regard to the traction and the staff employed.

This consideration is that the elevated points of a mountainous region are *productive* and not *wasteful.*

By the force of things, the greater part of the traffic goes down the descents; it is only the empty wagons which ought to go up the ascents.

In taking the precaution, then, in laying out the line to have the ascents as much as possible in the same direction, the traction of the serviceable load may be made to cost little or nothing, and the fact that the dead weight alone remains to be dragged up the ascents will show the importance of lessening it, and the value, from this point of view, of lines of narrow gauge.

III.—*On the Width of Line which ought to be Adopted by Preference.*

We have already said that we do not regard the narrow gauge as appropriate to the large currents of international traffic by which the continent is intersected. The speed of the passenger trains and the weight of the goods trains will always operate as a barrier.

But where for the first time the want of communication and the means of transport arises, the above conditions cannot be all at once realized.

The necessity of constructing and of working cheaply leads every judicious mind to prefer the use of a reduced width.

How far ought this reduction to go?

In general terms, this is a question that cannot be solved, and those who are most competent have shown by the contradiction which characterizes their solutions that the problem thus presented is beyond their reach.

Thus, the Russian commission of 1870 has adopted and recommended the Norwegian gauge of 1.067 metre (3 ft. 6 in.), and on that account no other gauge has been used in Russia.

Mr. Fairlie maintains that the gauge of 0.91 metre (3 ft.) gives the minimum of relation between the dead weight and the serviceable load of the wagons; according to him, if the line be made either wider or narrower, this relation increases.

Mr. Spooner admits that this limit goes to 0.76 metre (2 ft. 6 in.), for which he gives tolerably good reasons.

The German engineers were less absolute, and more correct when they said that it was of interest to every one—concessionnaires and workers—to have only two gauges, viz., 0.75 metre and one metre (2 ft. $5\frac{1}{2}$ in. and 3 ft. 3.37 in.).

Any country being given with a profitable traffic, estimated according to its nature and quantity, what was theoretical becomes practical and susceptible of solution.

If the passenger traffic is important, or if the greater part of the material to be transported is light and bulky, it is necessary to adopt a gauge of about a metre (3 ft. 3.37 in.), and construct lines, locomotives, and wagons as light as possible.

If, however, the traffic is in ponderous materials, such as the produce of mines, the gauge of 0.75 metre (2 ft. $5\frac{1}{2}$ in.) would unquestionably be the best, and would suffice for the transport of any other goods.

If it became a question of long lines, or of a system intended for the transportation of ores, it would be better to stick to a gauge of 0.60 metre (1 ft. $11\frac{1}{2}$ in.).

To sum up, then, let us have no absolute and abstract solutions, which only lead to grief, but a rational examination of the conditions of each line.

It is the prevailing nature of the traffic which must determine what kind of rolling stock must be used, and what width of line is the best to be adopted.

In a new country where a whole system has to be created, we must, so to say, imitate nature: we must construct, at a width of 1.50 metre (4 ft. 11 in.), those large arteries which, like wide rivers, are intended to be used for the transport of men and matter.

Next to that, let a line of 1 metre, like a large river, carry life and movement into provinces where the road exhibits few inequalities, and into agricultural districts, with their light and bulky products, and active passenger traffic.

Lastly, let a narrow way of 0.75 metre (2 ft. $5\frac{1}{2}$ in.) wind like a torrent through mountain gorges, carrying mineral products, and bringing them either to the wide line or the sea.

Thus, the question of an economical and profitable construction of a system of railways, corresponding to the rational requirements of traffic, will be resolved for all.

NAUTICAL METEOROLOGY.

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[From "Naval Science."

I.*

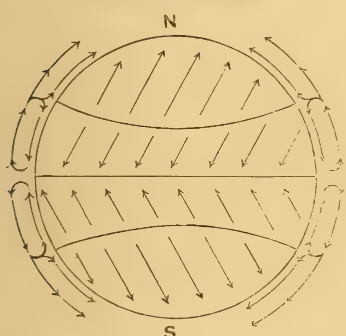
The word Meteorology is derived directly from the Greek, and signifies literally "the study of things above us;" but though the sun, moon, stars, and what are known collectively as the "heavenly bodies," are certainly above us, meteorology has little or nothing to do with them, not even with meteors. By modern use—for the word, with scarcely any difference, is in all European languages—meteorology means distinctly that science which treats of the *air*, its state and condition, the changes to which it is subject, and the phenomena which these changes give rise to. Now, the air is subject to a great many changes; and the science is really one of very wide scope, and has many different branches. It includes, for instance, all questions of medical climatology, such as the advantages of Nice, Algiers, Madeira, Ventnor, or Torquay as wintering places for invalids; it in-

* This is the first of the course of Lectures delivered at the Royal Naval College; the others will follow in succession.

cludes, again, all questions of climate as affecting agriculture, or the geographical distribution of plants and animals, and thus becomes intimately associated with the sciences of botany, zoology, and geography; whilst, as stretching into the distant regions of the air and the wide expanse of space, it is closely connected with astronomy.

Again, it includes all questions relating to weather; and this is, perhaps, its popular side, for the interest which attaches to weather is universal. We English are supposed to have a singular faculty of introducing it in conversation; and hosts of cheap almanacs turn a tidy penny every year by their appeals to the gullibility and ignorance of the public; for they are, really, unmitigated rubbish. Whatever advance we may be making in the scientific study of meteorology, we have as yet made very little indeed in that special branch of it which would foretell weather changes; we have scarcely, if at all, improved on the knowledge of the traditional shepherd of Salisbury Plain, who. on a bright sunshiny day, confidently warned the passing traveller of the coming shower, because, as it turned out on inquiry, he had noticed the ram of his flock scratching himself in a gorse-bush. There is no doubt about it; animals know a great deal more about the proximate weather changes than we do; and our finest and most delicate meteorological instruments are as yet, on this point, far inferior to their natural sensibility. It is indeed true that the Meteorological Office is often able to give warning of a change in the weather, sometimes even a couple of days before it comes on; but how? Simply by getting speedy knowledge of the weather actually prevailing or impending, of the changes actually going on in some distant place. A most elaborate network of telegraph wires connects the office in Westminster with stations scattered broadcast over England, Scotland and Ireland—nay, I should say, over Europe; and by means of these any atmospheric disturbance or change is known in the office almost as soon as it is in the country where it is taking place. Scientific study then comes into play; by long-continued observation and comparison it is now known that the gales which ravage our coasts almost (though not quite) invariably come in from the westward. No matter what the direction of the wind may be, west or east, south or north, the gale makes its first appearance on the west coast of Ireland, and the first notice of it comes to the Meteorological Office from Valentia or Galway; and it is by a comparison of the telegrams from these and other, more especially the intermediate stations, that the forecast is made and the warning transmitted to the several ports. But the knowledge which enables such a forecast to be made is evidently quite a distinct thing from a knowledge which would enable its possessor, from his own resources, and without extraneous aid, to tell what the weather is likely to be (say) to-morrow; or in any way at all, to tell what it is likely to be this day next year; in this we have simply made no advance whatever.

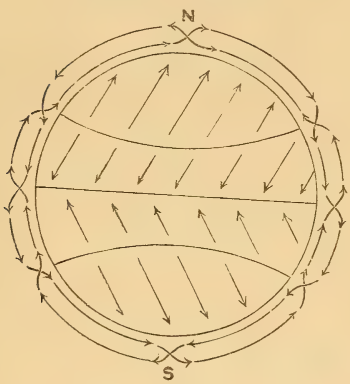
FIG. 1.
HADLEY'S THEORY.



The subject of these lectures, then, has no reference whatever to special prognostications of weather; on that point I am as ignorant as any of my neighbors. No! our subject here is that branch of meteorology which treats of the prevalence of certain weather at different seasons in different parts of the world, in different seas, on different coasts, and links itself closely with the study of natural, or, as it is commonly called, physical geography. For of this we really have some knowledge, and every day adds to it; every ship which sends a well-kept log to the Hydrographic Office, or to the Meteorological Office, renders that knowledge more certain and more complete; every traveller or explorer who brings home a sensibly kept journal contributes something to our information, and enables us to speak with greater accuracy and confidence as to the weather, the winds, the rainfall, the heat or cold which prevails according to the locality and the season.

But let there be no mistake as to my meaning. We can speak confidently as to the general run of wind or weather at any time, in any place; but distinctly, we do not assume a right to speak as to the particular weather on any particular day named. I will give you a familiar instance of this. It is pretty generally known that at the end of the year, we—here in London and its immediate neighborhood—are apt to get bad fogs; the

FIG. 2.
MAURY'S THEORY.



regular recurrence of these fogs is a distinct feature of our climate; and November is commonly spoken of as the month in which they are most frequent. Well, last November we had not one worth speaking of. A medical man, who has been practising here for more than thirty years, tells me that he does not remember such a November in the whole of that time. But, on the other hand, in the last week of October we had three or four days' fog, so thick that we could not see half-way across the street; and again, in the very beginning of December, we had a whole week of fog, still darker, still more dense, and so poisonous that it killed outright the fat beasts at the cattle-show in Islington, and doubled the death-rate of mankind in the metropolitan district. Now, as I have just said, these fogs could safely be predicted, not for any particular day, or week, but for the season; and any asthmatic or consumptive patient could be warned to get out of the way. And in exactly the same manner we can warn ships to look out for, and specially prepare for, bad weather at certain seasons in the several parts of the globe. We can do much more than this; we can confidently say of many localities the chances are that at certain seasons named such or such will be the wind or weather; and this nevertheless confidently because some individual ship, being there at that season, meets with weather of the very opposite description.

But since, after all, we can only speak of probabilities, is the knowledge of these probabilities worth having? A moment's reflection will show you that in everything you do you are guided by probabilities—that nothing is certain. And in the matter more especially before us, the probabilities I speak of have very practical value; for a careful and scientific study of these, as laid down by Captain Maury more than twenty years ago, had the almost immediate effect of shortening passages by about one-third, and of course of reducing the expense of the voyage, a saving which for the United Kingdom alone amounted to something like two millions sterling per annum, and for the whole world cannot be counted as less than five millions. You will find the statistics of this in the introduction to the *Physical Geography of the Sea*.

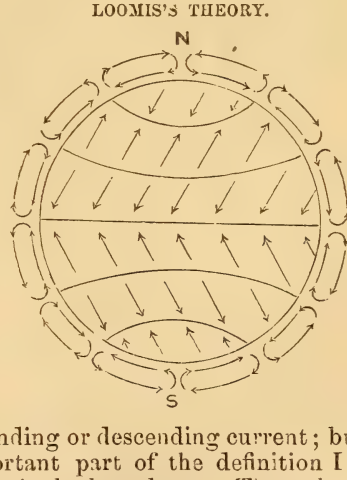
As I have mentioned this celebrated book, and its author, Captain Maury, I will take the opportunity of reminding you that, considered as an exact science, nautical meteorology owes its present development almost entirely to him. I shall, in the course of these lectures, have to point out instances of mistakes he has made, of opinions he held which later inquiry has proved to be incorrect; for when he wrote, the science was still in its infancy, and his means of accurate knowledge were limited, as compared with those now at our disposal; but that we can, in these matters, see further and more clearly than he could, is due to the painstaking manner in which he removed the obstacles that would have obscured our vision. No earnest student of nautical meteorology in the present day, however much he may differ from the opinions expressed by Captain Maury, will be disposed to depreciate his labors; none can avoid the consciousness that if he sees further than did Captain Maury, it is because he takes his stand on the scaffolding that Captain Maury erected. Lest, then, any remarks on Captain Maury's opinions, which I may hereafter find it necessary to make, should be considered as an attempt to extol myself at the expense of his reputation, I say now, and once for all, that I should be sorry to be so much misunderstood; and that, though differing from him on many and even important points, I am none the less, merely his follower and disciple.

I have spoken, then, of the money value of the probabilities which we have to study; but it is far from being merely a commercial matter; for, independently of the great fact that money is the sinew of war, and of modern war more especially, we can never allow ourselves to forget that the protection of our commerce is one of the most important duties which our Navy has to perform. In important crises, the making a rapid passage is of infinitely more consequence to a man-of-war than ever it can be to a merchantman; and it is the duty of a naval officer to be prepared for any emergency which can occur. Again, the conduct of actions, and still more of campaigns, has often, in times past, turned on a local knowledge of winds and currents; and if space permitted, I might cite numerous instances in which advantage has been gained by such knowledge, or lost for want of it. Assuredly if, so far as the merchant service is concerned, knowledge (in this respect) is *money*, in our own service it is emphatically, in the words of the old adage, *power*. Nor can this be considered an affair of the past; for though battles in future will be fought under steam, and the station to windward or to leeward will be a matter of little consequence, the fighting a decisive battle is but a small part of the duty of a fleet in time of war, and the blockade of an enemy's coast, or the maintenance of a distant station, must still be done to a great extent under sail. The undue employment of steam power under such circumstances would necessitate the expenditure of coal impossible, perhaps, to replace; and the fleet which should be found with empty coal-bunkers, in presence of the enemy, would be scarcely likely to add to our naval glories.

It is thus, then, that I wish to put the science of nautical meteorology before you as an important subject, calling for severe and exact study; not merely as the subject of lectures which you may leisurely listen to, or of a book which you may carelessly glance over. As intelligent men I invite you to it, as the science which examines into, traces, and expounds the phenomena with which your profession continually associates you; as naval officers I urge it on you as a science of practical utility, capable of developing in a marked degree the arts both of peace and war, of promoting or protecting commerce, and of helping, when need may be, in the maintenance of that proud position which we have inherited from our forefathers.

To begin, then, at the beginning. Wind is air moving parallel or nearly parallel to the surface of the earth, with a distinctly sensible velocity. Now, it is necessary to begin with this, for as in every branch of science false notions intrude if we have not accurate definitions, if we do not know exactly what we mean, or what others mean, by the terms made use of, so, in the case immediately before us, a vast amount of nonsense has been talked, on account of the meaning of the word wind not being properly understood. Wind is often said to be simply air in motion, which as a general statement is vague, but as a scientific definition is incorrect. Air may move perpendicularly to the earth's surface, but in such cases it is not called wind; it is an

FIG. 3.
LOOMIS'S THEORY.



ascending or descending current; but the important part of the definition I have given is the last clause. The velocity of the air is distinctly sensible; unless it is so there may be motion, but there is not wind. Thus, for instance, in any room there is a great deal of motion, caused not only by the unequal heating, but mechanically by the actual movements of every living thing in it, and markedly so in a lecture-room where a number of men are present; it has been repeatedly shown that a delicate anemometer will go round in consequence of the motion of the air caused by people getting up from their seats; but such motion as this is certainly not wind.

Numerous experiments of many kinds show that the motion of air is not distinctly sensible till it is nearly two miles an hour; and the Vienna Conference last summer agreed that motion under one mile an hour must be considered a *calm*.

Now the exact measure of the velocity of wind is a very troublesome operation, and, indeed, has never yet been satisfactorily made. The instruments used for this purpose are called anemometers, and are divided into two distinct classes, those which measure the pressure, and those which measure the velocity. In each class there are many different and ingenious patterns, into the details of which it is not necessary for me to enter, the general principle being the same throughout. In the first, the air moving against a certain flat surface of known area presses it in against a definite resistance, given either by a spring, or a weight solid or fluid. In the second, the air moving against certain small sails arranged round a rotating spindle, sometimes as hemispherical bowls, sometimes as the sails of a windmill, causes motion in some clockwork, which is indicated on a series of dials. Those that are almost invariably made use of in this country are, of the first class, Osler's anemometer, and of the second Robinson's. This last is indeed the only one that is at all common, and consists of four hemispherical bowls at the end of arms fixed horizontally on a vertical spindle.*

The principle of these instruments being so simple, it would seem that the determination of the wind's pressure or velocity ought to be a very easy and straightforward affair, and the change from pressure to velocity, or velocity to pressure, be a mere matter of arithmetic; for it is very well known from elementary dynamics that, in such cases, velocity varies as the square root of the pressure, or, in other words, that the numbers representing the velocity in miles, and the square root of the pressure in pounds, have to each other a constant ratio. But it has been found quite impossible to determine the value of this ratio; in fact, in practice it is found not to be a constant at all. This difficulty arises from the extreme irregularity and diversity of the motion in any current of air, which is such that the indications of a pressure anemometer not only vary continually from minute to minute, but also depend on the shape and size of the surface against which the wind blows. Thus the pressure on a surface containing two square feet has no fixed relation to that on a surface of one square foot; and not only that, but taking a uniform area of one square foot for the surface pressed on, the pressure is different, and in no constant ratio, according as the surface is circular, square, or oblong; or even, when oblong, according as the long side is horizontal or vertical. It is these curious and irregular differences which tend to show that measurement by pressure is of little or no value; and on this account scientific measurements are now made, almost entirely, in terms of velocity. But even this is by no means quite satisfactory; for it is found extremely difficult, and indeed impossible, to place the anemometer so that it may be entirely free from local influences; even where it is at a distance from houses and trees, there is generally some more or less trifling irregularity in the ground, which deflects the wind blowing from that direction, and either shelters the anemometer, or concentrates the current of air on it with exceptional force. It is thus continually found that velocity anemometers show a very marked difference between winds of the same estimated strength blowing from different directions—a difference which offers very great difficulty to any accurate determination of the velocity, or to laying down any fixed rule for estimating the force.

This, then, is the difficulty which stands in the way of the adoption of the Beaufort Scale as a strictly scientific notation of the force of wind. On board ship, the Beaufort Scale is understood as being used with a certain amount of latitude,

* For detailed descriptions of these and other anemometers, see Negretti and Zambra's *Treatise on Meteorological Instruments*.

and any officer in making the estimate is guided by many circumstances which long training at sea enables him to appreciate. On shore it is more difficult; and yet, in order to compare observations at sea with observations on shore, it is necessary that we should be able to reduce them to a common standard; that we should be able to say what velocity corresponds to the several numbers of the Beaufort Scale. This reduction has not yet been made with an exactness that can be depended on; and though the numbers in the middle of the scale may be considered as approximately determined, the different estimates which have been made for the numbers near the beginning or end have a wide range. I give here the velocities which I myself have proposed, and those which have been proposed by Sir Henry James and by Mr. Scott, the Director of the Meteorological Office*:

Number in Beaufort Scale.	Velocity in miles per hour.		
	Here proposed.	According to Sir Henry James.	According to Mr. Scott.
1	2	7	8
2	4	14	13
3	8	21	18
4	16	28	23
5	24	35	28
6	32	42	33.5
7	40	49	40.5
8	50	56	48.5
9	62	63	56.5
10	78	70	65
11	96	77	75
12	120	84	90

On every point connected with meteorology the opinion of Mr. Scott carries very great weight, and on this more especially, as it is one to which he has given much attention. My own estimate was formed long before I had an opportunity of seeing Mr. Scott's, and, indeed, before Mr. Scott's was altogether fixed; but, though I know the very great care he has taken in forming his estimate, I can scarcely agree with him that force 1 of the Beaufort Scale represents a velocity of 8 miles an hour; or that force 12 is adequately represented by a velocity of 90. As I have said, the difficulties in the way of satisfactorily measuring low velocities with a Robinson's anemometer are almost insuperable; and it may fairly be doubted whether the extreme velocities can ever be more than guessed at. I purposely, therefore, leave the question undecided; but whatever opinion may be formed, I have said enough to show that the commonly received definition that wind is air in motion has no scientific meaning; and that, whether we consider force 1 as denoting a velocity of 2 miles an hour, or 8, there may be a good deal of motion in the air without there being any wind at all.

It follows, therefore, that in examining into the forces which cause, or have been supposed to cause, wind, it is not sufficient merely to show that they are capable of causing motion; it is necessary to show further that they are capable of causing that amount of motion which constitutes wind; and I call earnest attention to this necessity, for it is one that has been much overlooked, and its neglect has led to much confusion and difficulty.

Now, the first and most evident cause of wind is heat, or, more strictly speaking, difference of temperature. It is very familiarly known that, as a general rule, almost without exception, heat causes bodies to expand, and that when a body is so expanded it is relatively lighter than it was before; its weight is distributed over a larger volume, so that its specific gravity is less. Just the same as any other substance, air is expanded by heat, and becomes specifically lighter. If, then, there are two masses of air in contact, and one of these is heated and made specifically lighter than the other, the heavier presses in underneath the lighter, and forces it up. It is not correct to say (as is very commonly said) that the lighter of the two rises, and the heavier pours in, to take the place left vacant. If you take a piece of cork and thrust it to the bottom of a basin of water and there leave it, it is not *scientifically* correct to say that the cork rises to the top, and the water pours into the vacant space; what takes place is this: the water being more strongly attracted towards the earth than the cork, presses in underneath the cork, and so thrusts the cork up; it exerts a distinct pressure on the under side of the cork, and without that pressure the cork will not move. In the same way, a bal-

*For further information on this subject, see a paper by Mr. Scott in the *Quarterly Journal of the Meteorological Society* for July, 1874.

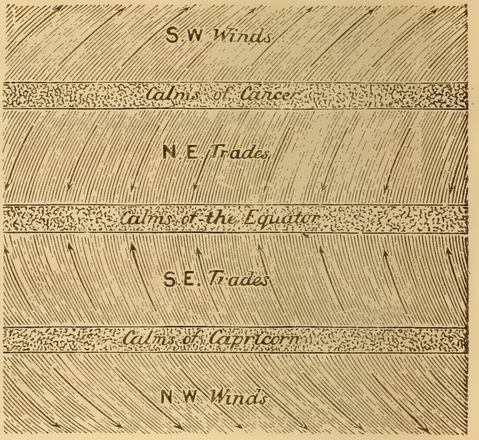
loon filled with hydrogen, or other light gas, is lifted by the pressure of the surrounding air; and still in the same way, a quantity of air that has its temperature raised is thrust upwards by the adjacent air whose temperature has not been raised.

But the way in which this is commonly described is incorrect and confusing; it directly implies that the heated air rises of its own accord and leaves its former place vacant, into which vacant place the adjacent air "rushes;" it implies that the force which causes the motion is the whole weight of the adjacent air which rushes in, instead of being merely the difference of the weights of the two adjacent volumes; it implies that the air rushes in unopposed, instead of having to thrust the other air out. I do not for a moment suppose that such misconceptions exist in the minds of the many able men who have fallen into the popular and loose way of speaking on this point; but I know that they do exist in the minds of many who have not given the subject due attention, and have unthinkingly adopted incorrect phrases and erroneous ideas; and it is on this account that I dwell so persistently on what is really a very elementary problem of hydrostatics.

When, then, two masses of air, of different temperatures, and, therefore, of different specific gravities, are in contact, and the one forces itself in underneath the other and lifts it up, as it does so it has a motion more or less nearly horizontal, and becomes wind if, as has been strictly defined, that motion is such as to be distinctly sensible. Of such sensible motion we have a familiar example in every fire where there is what is called a good draught—that is, where the heated air, instead of being allowed to warm the room, is driven up the chimney and expelled. On a larger scale, but in exactly the same way, air is put into every sensible motion for the purpose of ventilation, both in public buildings and in mines; and it is the same way that differences of temperature at different parts of the earth's surface, at different seasons, or at different times of the day, have been described as producing very marked winds either permanent or periodic.

The first attempt at a scientific explanation of the principal permanent and periodic winds, by reference to differences of temperature was published by Halley in 1686,* and is worthy of notice as being the outline of the theory which is still widely accepted. He argues that since air, which is less rarefied by heat, must have a motion towards those parts where it is more rarefied, and since the meridian of greatest heat is, by the sun's daily motion, continually carried towards the west, the air, which tends toward that meridian of greatest heat, must also continually move towards the west; that thus a general easterly wind is formed, so that the particles of air impel one another and so keep moving until the next return of the sun; and thus the easterly wind is made perpetual. And again, that since the air at the equator is necessarily much more rarefied than the air at

FIG. 4.
SYSTEM OF WINDS.



the tropics, and at still greater distances, it follows that the air in both hemispheres forces itself in towards the equator, and thus gives rise to a perpetual wind from the north-east or from the south-east. He argues further, that this rarefied air near the equator, being ascended, must disperse itself; that the upper air must, *by a contrary current*, move from those parts where the heat is greatest, that so, *by a kind of circulation*, the north-east wind has a south-west wind above it, and the south-east wind has a north-west wind above it.

The defects of this theory, known as Halley's, are apparent; such an expression as "a kind of circulation" is vague, and in no way explains the existence of these

* "Philosophical Transactions," vol. xvi.

contrary currents above the lower; nor does it show why the air, flowing in towards the place of greatest rarefaction, should not meet the sun instead of following it; why, in fact, there should not be a perpetual westerly wind instead of a perpetual easterly wind, as stated; and more especially it implies that these north-easterly and south-easterly winds must prevail in all latitudes, and takes no notice of the westerly winds which we know prevail in many parts of the temperate zones. It can, in fact, be considered only as an imperfect sketch which was left for later writers to complete.

Accordingly, in the year 1735, George Hadley published* an amended theory, in which he argues that the easting of winds near the equator cannot be due to the cause assigned by Halley, since air must necessarily flow towards the place of greatest rarefaction, from all directions, and as much from the west as from the east. Whilst, therefore, he accepts Halley's argument as showing that we ought to find northerly or southerly winds on each side of the equator, he maintains that air so moving towards the equator becomes deflected towards the west, by reason of the earth's rotation, and the very different velocity of rotation on different parallels of latitude. He argues that since the circuit of the equator is greater than that of the tropics by about 2,083 miles, and the surface of the earth at the equator moves so much faster than the surface of the earth *with its air* at the tropics, it follows "that the air, as it moves from the tropics towards the equator, having a less velocity than the parts of the earth it arrives at, will have a relative motion contrary to that of the diurnal motion of the earth in those parts, which, being combined with the motion towards the equator, a N. E. wind will be produced on this side of the equator, and a S. E. on the other." These winds, he continues, "as the air comes nearer the equator, will become stronger, and more and more easterly, and be due east at the equator itself;" where we ought, therefore, to have a constant easterly gale of 80 miles an hour, did not the friction against the earth's surface reduce it to the velocity of a gentle breeze. He goes on to show that the heated air which is raised from the neighborhood of the equator must "spread itself abroad over the other air, and so its motion in the upper regions must be to the N. or S. from the equator;" that after some time, and having moved some distance from the equator, it will lose part of its heat, and its density being thus increased, it will again approach the surface of the earth; that having, at the equator, attained the velocity of the surface of the earth at the equator, it has a greater velocity than the parts of the earth where it descends, and thus becomes a westerly wind, or rather by reason of its motion also from the equator, a south-westerly wind in the northern hemisphere, and a north-westerly in the southern; "and thus the air will continue to circulate, and gain and lose velocity by turns from the surface of the earth or sea, as it approaches to or recedes from the equator."

* "Philosophical Transactions," vol. xxxix.

This theory of Hadley's has met with very general acceptance, though later writers have slightly modified some of its minor details. Sir John Herschel in particular* considers that the easterly direction of winds approaching the equator must continually diminish, in consequence of the very slight difference between the successive parallels, and of the continuous friction on the earth's surface: that these winds therefore become more and more nearly north and south, and that as winds due north and south they meet at the equator, neutralize each other, and produce a calm. It is this system of winds, so modified, that I have shown in Fig. 4; whilst the circulation of the air, as described by Hadley, is shown in Fig. 1.

But Captain Maury has proposed a still further modification, not, indeed, affecting the general system of winds, but in the details of the circulation, which it is necessary to notice. He considers that there is evidence of a continuous change of the air from one hemisphere to the other, and suggests that the air from the northern hemisphere and that from the southern cross through each other as they ascend at the equator; and that any particular particle of air moves continuously from pole to pole, rising and falling in accordance with Hadley's theory, but still moving on.

* "Outlines of Astronomy," § 243.

It is impossible to consider this theory as anything more than a speculation, introduced to explain facts which themselves rest on very inadequate evidence; for neither in free nature nor in experiment have we any instance of currents of any fluid crossing through each other in the manner he has described. In avoiding this difficulty, Professor Loomis has proposed a modification of this theoretical circulation of the air; he does not, however, give any clear explanation of the air forming ascending currents near the parallels of 60°; nor, does it appear why that portion of the air which, in the temperate latitudes, blows towards the equator as an upper current, should descend near the tropics and reverse its direction, so as to blow from the equator.

The reputation of Captain Maury and of Professor Loomis seems to me sufficient reason for showing the theoretical circulation which they have put forward; neither the one nor the other is essentially different from Hadley's, and the minor details which they have introduced have not been generally accepted. I do not propose, therefore, to examine further into these details, but shall recur to the broad principle as enunciated by Hadley in my next lecture.

THE MECHANICAL EQUIVALENT OF THE HEAT UNIT.

By FRANCIS L. VINTON, A.M., C.E.

Written for VAN NOSTRAND'S MAGAZINE.

THE dynamic equivalent of one thermal unit is one of the most interesting, not to say important factors just now, in all mechanics, theoretical or applied, and yet it seems to be little understood. In the first place no heat whatever is necessarily used or absorbed by a gas in simply expanding. Soule showed as long ago as 1845 that unless a gas during expansion operates some outside work besides expansion, such as lifting the atmospheric column, its temperature and its quantity of heat undergo no change.

This, moreover, is the basis of the whole mechanical theory of heat. Your correspondent on page 400, in November ECLECTIC, has properly calculated the amount of heat employed in overcoming the atmospheric pressure, while a certain volume of air expands a certain amount, and from that has shown as hundreds have done, that the theoretical equivalent deduced from the consideration of sp. heats, is very near Soule's equivalent determined by experiment; the difference being only a few foot pounds, 5.2, according to his numbers. If that air had, however, expanded into a vacuum, the variation of volume and pressure would not have affected the apparent sp. heat of air—there would have been no depression of temperature, no latent heat absorbed as some say. This last expression, however, is one which no authority will make use of at the present day, without at least explaining that it is, like the denomination *force of inertia*, *living force*, and some other terms, entirely inappropriate and even deceptive.

The subject would lead to a volume. I will therefore only refer to another loose phrase which sometimes leads to fighting shadows; namely: "The dynamic equivalent of heat." There is, in fact, no dynamic equivalent of heat any more than there is of gravity—both would be infinite to us; there is, however, a mechanical equivalent of a unit of gravity, namely, one foot pound, or one kilogrammetre, according to the units of weight and space which are assumed. There is also a mechanical equivalent of a unit of heat, say 772 foot pounds or 425 kilogrammetres, and both mean the total molar work, independent of molecular, that a certain quantum of the force can effect operating over a certain space; to explain more fully, one unit of weight acting through one foot space can lift one pound one foot, and one unit of heat acting through one foot space can lift 772 pounds one foot.

EFFICIENCY OF FURNACES BURNING WET FUEL.

As Determined by Experiments on a Large Scale.

BY PROFESSOR R. H. THURSTON.

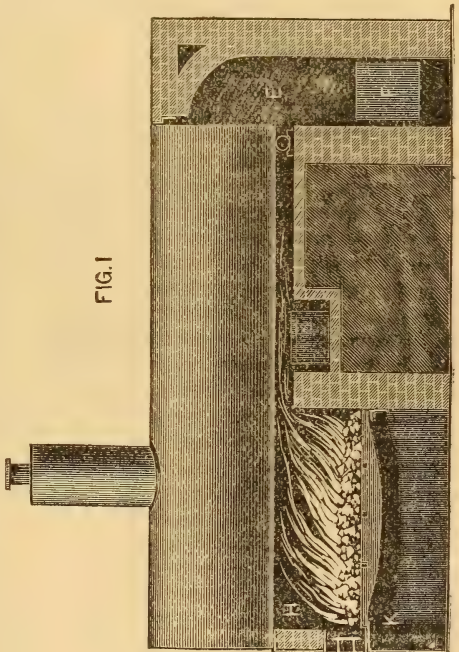
From "The Transactions of the American Society of Civil Engineers."

1. The writer was recently called upon, in the course of professional practice, to determine the relative economical value of two forms of furnaces which were in use for burning wet fuel.

The use of fuel, like spent tan or sawdust, actually wet with water or sap, is so unusual, and is so seldom seen by the engineer, that a detailed account of an experimental investigation made upon two distinct varieties of furnace burning spent tan, wet from the leaches, will probably be considered as important and interesting by the other members of the Society as it was by the writer.

2. Formerly, it was thought impossible to burn this waste product of tanners, and it was either thrown away, at considerable expense for carting, or was mixed with dry wood or other good fuel at some cost, or it was dried in the open air by the sun, or by artificial heat in kilns. Within a few years it has been found that, with exceptional skill on the part of the fireman or "stoker," it could be burned with some success in furnaces only differing from those of ordinary construction by having a brick arch turned above the grates; in others having "cone" grates with special arrangement and proportions of air space; and with excellent results in a furnace having an overhead brick arch, with a grate so proportioned that a considerable amount of fuel could fall into the ash-pit and burn there, and with the separate "ovens," two or more in number, so arranged that the products of active combustion in one furnace should be mingled *en route* to the boilers, with the products of distillation and with moisture expelled from the fuel, in a similar adjacent "oven," or furnace, which fuel was, at the same time, drying under the heat radiated from the furnace walls and arch, and received from the fire in the ash-pit, thus desiccating preparatory to subsequent combustion. The latter requisite of preliminary desiccation was secured also by a system of "alternate firing" of the separate feed-holes in the same oven.

3. The secret of success would seem to be—as indicated by the examination of a large number and of a considerable variety of furnaces burning spent wet tan with more or less success—the surrounding of the mass of wet fuel so completely with heated surfaces and burning fuel that it may be rapidly dried, and then so arranging the apparatus that thorough combustion shall be secured, and that the rapidity of combustion be very precisely



equal to and shall never exceed the rapidity of desiccation. Where this rapidity of combustion is exceeded, the dry portion is consumed completely, leaving an uncovered mass of wet fuel which refuses to take fire, and then combustion ceased entirely.

In the ordinary steam-boiler furnace, Fig. 1, wet fuel has never, so far as the knowledge of the writer extends, been burned with even approximate success. Withdrawing the grates from under the boiler, and securing a reservoir and radiator of heat, by throwing over them a brick arch, as in Fig. 2, gives a form of furnace, known either as a Morrison or a Crockett furnace, in which wet fuel has been burned with partial success, and when the grates are so set that some fuel may fall into the ash-pit as it dries, and there burn, the conditions become those of the second case to be described. The use of the form of grate—shown in Fig. 3 (enlarged in Fig. 4)—giving ample space for fuel falling into the ash-pit, ensures still freer combustion. This peculiar

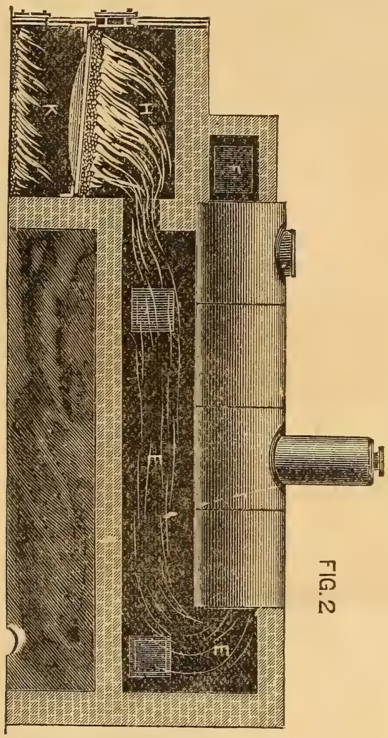


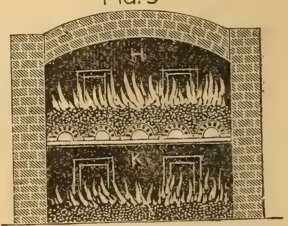
FIG. 2

form of section also secures freedom from warping when highly heated.

The first example of a furnace burning wet tan of which the efficiency was determined by the writer was of the kind known as the "Thompson Furnace," which embodies all of the favorable conditions described in the preceding paragraph. This furnace is shown in section, Fig. 5.

There were six "ovens" placed side by side, in two sets of three each, the chimney rising between them as shown at *A*. The grate surface of each oven was 9 feet long, and 4 feet 4 inches wide, giving a total area of 234 square feet. Each furnace was charged through two holes, *B* and *C*, in the top of the furnace arch, the proper method being to fill these holes alternately. The grates were of fine brick, spaced about ⅝ inch apart, and supported along the middle line of the ash-pit by a brick wall. The thickness of these grates was nearly 3 inches. They were in four pieces, breadthwise the furnace, a pair on each side the middle wall supported by abutting against each other in a manner somewhat resembling an arch

FIG. 3



of but two voussoirs. Two doors at the end of each ash-pit permitted cleaning to be readily effected. The gaseous products of combustion leaving the furnaces entered a "mixing chamber" *D*, common to each set of furnaces, and thence passed through the flues *E E* to the extreme end of the boilers, returning through the tubes to the smoke-boxes *F*, and through the iron flue *G* to the chimney.

5. The steam-boilers were three in number, of the plain multi-tubular variety. Two were 4 feet in diameter, 14 feet in length, and contained 32 four-inch

FIG. 4

tubes each; the other was 5 feet in diameter, 12 feet long, and contained 78 three-inch tubes. The total heating surface, reckoning all of the tube surface, one-half the surface of the shell, and all of exposed surface of the tube plate, was approximately 2,000 square feet. Of this a portion was ineffective, the lower tubes being choked with ashes, and the remainder was partly covered with deposit. The chimney was 90 feet high.

6. The feed-water was heated in a closed heater by the exhaust steam of the engine driving the machinery of the tan-

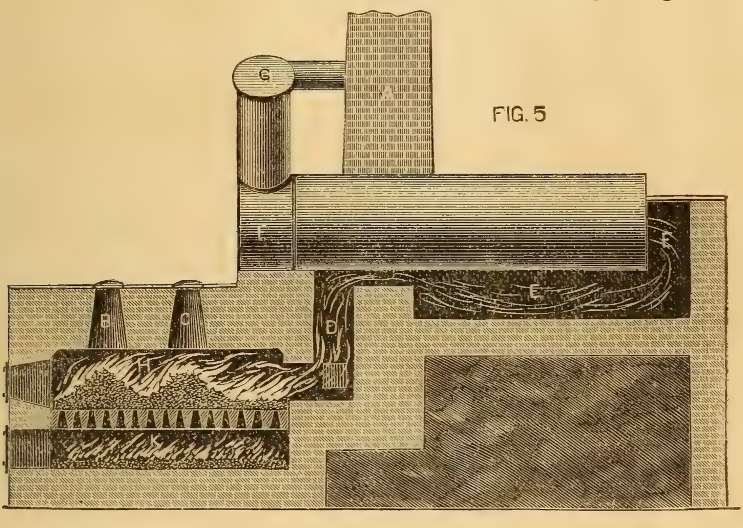
nery, very nearly if not quite to the boiling point. The exhaust steam mingled directly with the water. On reaching the tank in which the water was measured the feed water had cooled down to 205° Fahr.; thence it passed through the pump, and a considerable length of pipe across the street separating the engine from the boiler-house, and finally, around to the back end of the boilers, where branch pipes conducted it to each boiler.

The temperature of the feed when entering boilers could not, of course, be determined, but it was probably at least as low as 190° Fahr., which is the temperature assumed in the estimate of efficiency, and it may have been somewhat lower.

8. Commencing at 9 o'clock A. M., the trial continued until the remaining 7.7 cords were burned, closing at 10 o'clock P. M.

9. The feed-water was measured by cutting the feed-pipe between the heater and the feed-pump, and conducting the water from the former into a wooden box 18 inches wide and 4 feet long. The pump drew the water from this box, which ordinarily stood full to the top. Occasionally, the water supply from the heater was shut off, and the time which was occupied by the pump in reducing the level of the water one foot was noted. This was invariably very precisely 4 minutes. The quantity of water pumped into the boiler from the beginning to the end of

FIG. 5



the trial was 5.625 pounds, or 90 cubic feet per hour.

7. The measurement of the fuel was made as it lay on the leach, before it was disturbed for the purpose of being removed to the boiler-house, this precaution being taken to avoid error arising from possible changes of volumes due to such disturbance. In one case this transportation to the furnace was performed by a screw, as grain is sometimes moved, and in the other case by cars, capable of carrying nearly a cord, into which the tan was thrown from the leach by hand, and then was dumped at the furnace doors. A careful measurement showed the full leach to contain 8.04 cords of tan. From this 0.34 cord was taken to be weighed after being compressed until it was, as nearly as could be judged, as compact as when in the leach.

10. The capacity of the pump was originally barely equal to the requirements of the case, and, at this time, its valves leaked somewhat, making it necessary, not only to run the pump at its full speed throughout the trial, but to keep the fires considerably below their maximum intensity to avoid the necessity of putting on the steam auxiliary to prevent the water getting dangerously low. The maximum evaporation on the trial was thus determined by the capacity of the pump. The flue dampers were kept, as an average, something more than half open. The engineer estimated that he could have burned the fuel with nearly 50 per cent. greater speed, obtaining a proportionally

increased evaporation, could the pump have supplied so much water.

11. The spent tan, coming directly from the leach, was so wet as to part with its water when squeezed, wetting the hand. It had been simply drained a few hours, and was as wet as it could be without dripping. The percentage of moisture is given below.

12. As the result of the trial was considered a matter of great importance, both directly and indirectly, it was essential, not only to determine the amount of water entering the boilers, but to determine as accurately as possible the quality of the steam made, thus ascertaining how much was "primed" over from them unevaporated. As, under the conditions of this trial, each pound of steam obtained from the fuel about eight times as much heat as was taken up by water "primed" out of the boiler, the serious error which might arise by crediting the fuel with the evaporation of all water entering the boiler, in cases where even a moderate amount of priming occurred, is evident. Instances sometimes occur in which more water passes off unevaporated than is actually turned into steam. At least one instance has occurred in the experience of the writer in which the average amount of water primed exceeded by more than 100 per cent. the weight of steam made, the percentage of priming, as the expression is used in this paper, being over 60 per cent. The error arising from the neglect of this circumstance told nearly proportionally in favor of a really very poor boiler. A good boiler ought not to "prime," when working properly, over 10 per cent. when unprovided with superheaters; 5 per cent. priming would represent good work, and as low as 3 per cent. has been attained.

13. The first precise determination of the amount of priming in steam boilers was probably made by the writer in November, 1871, at a competitive trial of 5 steam boilers entered at the Exhibition of the American Institute, the trial being made at the request of a Committee of Judges of which he was then Chairman.*

In that instance, a large surface condenser of about 1,100 square feet area of condensing surface was used, in which all the steam made by the boiler on the trial was completely condensed. The water fed into the boiler was measured by a meter, and, on issuing from the condenser, was again caught in a tank. The condensing water, which amounted to some 10 tons per hour, was measured by a meter.

The temperature of the injection and discharged water, of the feed, the steam, the water of condensation, and of the escaping products of combustion, were carefully ascertained by suitably arranged thermometers and pyrometers, and were recorded in a log kept by selected students of the Stevens Institute of Technology. The fuel and the ashes were weighed, and all data were obtained and recorded with the greatest possible care.

14. The tabular statement of the results, as given in the report of the Committee, is reproduced as they are not otherwise obtainable by engineers generally, and as they are interesting and valuable in themselves, and particularly, as affording a useful standard with which to compare the results obtained during this trial of tan-burning furnaces. The method of determining the percentage of priming will be given below. It should be stated that the Root and the Allen steam boilers were of the "safety" or "sectional" class; the Phleger boiler was also composed of small tubes, but was surmounted by a large drum which was intended to contain some water, thus differing essentially from the two preceding in construction, and in the fact that no portion of the heating surface was above the water-line. The Root and Allen boilers both had a considerable amount of superheating surface. The Lowe and the Blanchard were peculiar forms of multitubular boiler, the former being distinguished by having a peculiarly designed combustion chamber, and the latter by its unusually large proportion of heating surface, as compared with the area of grate, and by its dependence upon a forced draught. All of these boilers gave exceedingly creditable results at this test.

16. A very neat apparatus has been invented by Leicester Allen, of New York, for determining the quality of the steam furnished by a steam-boiler. One of these instruments was made under the direction of the writer, for a committee of the American Institute, and used in

*Trans. American Institute, 1871–2; Journal Franklin Institute, 1872; Van Nostrand's Engineering Magazine, 1871.

15. Results of the Competitive Trial of Steam Boilers at the Fair of the American Institute, November, 1871.

NAME.	Square Feet.		Ratio of heating surface to grate surface.	Total Weights.					Ratio of water primed to water evaporated.	Mean Temperatures.						
	Grate surface.	Heating surface.		Coal.	Combustible.	Feed.	Steam.	Primed water.		Injection.	Feed.	Water of condensation.	Discharge.	Steam.	Superheat.	Flues.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.
Root.......	27	876½	32.5	3 800	3 185.5	27 896	27 896	0.	0.	45°.94	45°.94	58°.31	143°.1	334°.6	16°.08	416°.6
Allen	32¼	920	28.5	5 375	4 527	39 670	39 670	0.	0.	45°.5	45°.5	63°.48	154°.76	330°.63	13°.23	345°.87
Phleger ...	23	600	26.1	2 800	2 274	20 428	19 782.94	645.06	3.	45°.65	45°.65	54°.38	120°.83	321°.06	0°.	503°.76
Lowe	37¾	913	24.2	4 400	3 705	34 000	31 663.35	2 336.65	6.	45°.0	45°.0	54°.8	131°.5	319°.48	0°.	389°.6
Blanchard .	8½	440	51.8	1 232	1 047.5	10 152.5	9 855.6	296.9	3.	44°.4	44°.4	49°.49	106°.14	323°.75	0°.	221°.67

Results, etc.—(Continued.)

NAME.	Total British thermal units.	Total units per pound of combustible.	Apparent Evaporation.				Actual Evaporation.		Equivalent evaporation of water at 212° Fahr. and atmospheric pressure.	Square feet of heating surface required to evaporate one cubic foot of water per hour.	Coal, lbs. per square foot, grate surface per hour.	Efficiency; actual evaporation of fuel divided by theoretical.
			Per pound of coal.	Per pound of combustible.	Per square foot of grate surface per hour.	Per square foot of heating surface per hour.	Per pound of coal.	Per pound of combustible.				
	Q.	R.	S.	T.	U.	V.	W.	X.	Y.	Z.	Z 1.	Z 2.
Root..........................	32 751 834.34	10 281.53	7.34	8.76	86.09	2.65	7.34	8.76	10.64	23.59	11.73	0.709
Allen..........................	46 387 827.1	10 246.92	7.38	8.76	102.51	3.59	7.38	8.76	10.60	17.41	13.88	0.707
Phleger.......................	23 966 685.39	10 143.66	7.26	8.95	73.70	2.83	7.07	8.70	10.49	22.74	10.13	0.699
Lowe..........................	37 228 739.072	10 048.24	7.68	9.12	75.06	3.10	7.20	8.55	10.40	21.63	9.71	0.693
Blanchard.....................	11 485 777.35	10 964.94	8.24	9.69	99.53	1.92	8.00	9.41	11.34	33.48	12.10	0.756

1872, together with the apparatus already described, at the American Institute Exhibition of that year.

17. At the trial about to be described, it was impossible to condense all the steam made, and as no "Allen Calorimeter" was obtainable, it became necessary to improvise apparatus for the occasion. The steam-pipe leading to the engine was tapped by a piece of gas-pipe, on which was fitted a stop-valve. From a short piece of pipe attached to this stop-valve a length of india-rubber hose was led to a convenient point beside the boilers, where a barrel was mounted on an accurate platform scale; 200 pounds of water were carefully weighed into this barrel, and when the scale beam precisely balanced, the weight was set ahead 10 pounds. A very accurate thermometer, which had been provided by the writer, completed this crude yet satisfactory arrangement.

At intervals during the trial the stop-valve was opened, and after allowing steam to blow through the hose freely until all water was expelled, and the hose was so thoroughly heated as to insure that no loss of heat, by the steam flowing through it, should produce condensation and render the results inaccurate, the end of the pipe was plunged into the water contained in the barrel, and the issuing steam allowed to condense until the rise of the scale beam proved 10 pounds of steam to have been added to the weight originally placed in the barrel. The temperature of the water was carefully observed at the beginning and at the end of the experiment, and the rise of temperature recorded as a basis for the estimates of priming to be given.

13. It was considered advisable to ascertain, if possible, the temperature of the products of combustion escaping to the chimney. No pyrometer was obtainable, and it became necessary to improvise another arrangement for this purpose. A mass of iron, weighing 60 pounds, was found and placed in the flue leading from the boiler, where it, after a time, attained the temperature of the gases flowing past it. A wooden vessel of convenient size and shape was obtained, and 50 pounds of water were carefully weighed into it. At intervals of two or three hours the iron was suddenly removed from the flue and dropped into this water. The initial and final temperatures were noted, and, with the range, recorded for use in calculating the temperature of the waste products of combustion. The pressure of steam was observed hourly.

19. The collated observations gave the following data:

Mean steam pressure during trial.....71.4 pounds.
Total amount of spent tan burned.... 7.7 cords.
" " " water fed to boilers 73 125 pounds.
Temperature of water entering boilers 190° Fahr.
" " in determining priming:

	Initial.	Final.	Range.
1st observation	60°	110°	50°
2d "	63°	124 (116°?)	52° (?)
3d "	62°	115°	53°

Temperature of water in determining temperature of flues:

1st observation	65°	119°	54°
2d "	63°	112°	59°

Weight of one cord of wet spent tan, as measured in the leach.................5 447.7 pounds.
Length of trial .... 13 hours.

20. The determination of the total heat derived rom the cord of fuel is the first and most important problem. To solve it, it is necessary to know the temperature and weight of feed-water, the weight of steam produced and its temperature, the weight of water heated to the temperature of the steam, but not evaporated, and the quantity of fuel consumed. From the data obtained we can readily ascertain the total number of units of heat utilized per cord of wet fuel burned.

21. It is first necessary to calculate what portion of the 73 125 pounds of water passing through the boiler, was actually evaporated. Each pound of steam produced required for its generation the quantity of heat needed to raise it from the temperature of the feed-water to that due the pressure under which it was formed, and to vaporize it at that temperature. Each pound of water carried away in suspension by the steam only absorbed from the fuel the amount of heat needed to raise its temperature from that of the feed-water to that of the steam.

In heating the water in the calorimeter used in testing its quality, each pound of steam gave up an amount of heat equal to that which would have been required to raise its temperature from that of the mass in the calorimeter at the end of the experiment to that of the steam in the boiler, and to evaporate it at the latter temperature and pressure.

Each pound of water entering the calorimeter surrendered a quantity of heat equal to that needed to raise its temperature from the final temperature of the calorimeter to that of the steam under boiler pressure.

22. The total amount of heat being the sum of these two quantities, we may construct an algebraic equation which shall embody all the conditions of our problem.

Let $H =$ the number of heat units per pound of steam, h, = the number of heat units per pound of water, $U =$ total heat transferred to calorimeter, $W =$ total weight of steam and water, $x =$ total weight of steam alone, $W - x =$ weight of water alone.

$$\text{Then } Hx + h(W - x) = U; \text{ or } x = \frac{\frac{U}{h} - W}{\frac{H}{h} - 1}$$

23. At the first experiment, the steam pressure, per gauge, was 75 pounds. The temperature of steam at this pressure is 320° Fahr. The "total heat" of steam at 320°, from 0°, and at 75 pounds pressure, is (320—212)0.305+212+66.6 =1 211.5°.

The heat transferred to the calorimeter, per pounds of steam, was therefore, 1 211.5 — 110 =1 101.5 thermal units in this experiment.

The heat transferred, per pound of water, was 320—110 = 210 thermal units.

The total quantity of heat transferred to the 200 pounds of water by 10 pounds of mingled steam and water, was 200 (110°—60°) =10 000 thermal units.

$$\text{Finally, } x = \frac{\frac{10\,000}{210} - 10}{\frac{1\,101.5}{210} - 1} = 8.87 \text{ pounds steam.}$$

$$W - x = 10 - 8.87 = 1.13 \text{ pounds of water.}$$

The percentage of priming was therefore 11.3. The ratio of weight of steam and water was $\frac{8.87}{1.13} = 7.85$, the water being $\frac{1.13}{8.87} \times 100 = 12.74$ per cent. of the steam.

24. The other experiments were made with the steam pressure as before, and in the second the valve of $W - X$ comes out negative, indicating superheating. This may possibly have actually occurred as a consequence of the water having fallen slightly below the upper row of tubes in one boiler, but it is more probable the reading 124° does not represent the mean temperature of the mass of water in the calorimeter. In this experiment, the water was not as carefully stirred with the thermometer as in the other experiments, and the temperature was taken at the surface of the water, after a first and otherwise satisfactory reading of 116° had been obtained, but a second application of the steam jet had been necessary to accurately balance the scale, which heated the surface above the average temperature of the mass previously heated. The true reading can probably have been no higher than 116° or 117°, and it is taken for purposes of calculation at the former figure, although the lowest unrecorded reading finally actually obtained at the middle of the well-stirred mass was 116°.

$$\text{Then } x = \frac{\frac{10\,600}{204} - 10}{\frac{1\,095.5}{204} - 1} = 9.6 \text{ pounds steam.}$$

and the weight of water being 10—9.6 =0.4, the percentage of priming was 4, and the water carried over weighed $\frac{0.4}{9.6}$ + 100 = 4.3 per cent. as much as the steam with which it was mingled.

In the third experiment

$$x = \frac{\frac{10\,600}{205} - 10}{\frac{1\,096.5}{205} - 1} = 9.59;\ W - x = 0.41.$$

The percentage of priming was 4.1, and of water to steam 4.2 per cent.

The mean percentage of priming was 6.47. The mean percentage of steam alone was 93.53.

25. The total quantity of heat derived from the fuel and taken up by the boilers can now be divided into two portions and each calculated.

The total weight of steam produced was......,.. 73 125 x .9353=68 393.8.
The total weight of water primed was......... 73 125 x .0647 = 4 731.2.

The mean pressure at which the steam was formed being 71.4 pounds, we find its "total heat" per pound to be 1 210.6 thermal units, and the heat communicated to each pound of feed entering at 190° and evaporated at this pressure, 1 020.6 units. The average heat received from the fuel by each pound of water not evaporated was 127 thermal units.

Then 68 393.8 x 1 020.6 = 69 802 712.3 units,
and 4 731.2 x 127.0 = 600 862.4• "

Total heat from the fuel = 70 403 574.7 thermal
70 403 574.8 units.]

Total heat per cord tan $\frac{70\ 403\ 574.8}{7.7}$ = 9 143 321.4 units.]

26. The usual standard, as generally accepted by engineers in examples of this kind, is the evaporation of one pound of water, at the boiling point, and under atmospheric pressure.

The heat required is the latent heat at 212°, or 966.6 thermal units per pound. We have therefore—

Equivalent evaporation, by one cord of wet spent tan, from 212°, under atmospheric pressure,

$$\frac{9\ 143\ 321.4}{966.6} = 9\ 459.2 \text{ pounds of water.}$$

27. Under these conditions, 10 pounds of water would be considered a fair evaporation per pound of good coal, and in this example therefore, the furnace utilized from each cord of tan the equivalent of 946 pounds of coal.

28. A quantity of the tan was placed in a "fruit jar," and hermetically sealed. This tan was carefully weighed by Prof. Geyer, at the Stevens Institute of Technology, dried by exposure to the air in the study of the writer for one week, and then again weighed by Prof. Geyer, in the presence of the writer. The weights, before and after drying, were respectively 656.8 grammes, and 268.8 grammes. This fuel contained, therefore, 59 per cent. water, and but 41 per cent. woody fibre. The weight of a cord of this tan, measured in the leach, and then well dried in the open air, would be 2 233.56 pounds, and the equivalent evaporation per pound becomes 4.24 plus that of the water contained in the fuel, say 1.44, or 5.68 pounds water per pound of combustible.

29. The determination of the temperature of chimney flue, or of the escaping gaseous products of combustion, is thus made. At the first observation, 50 pounds of water were heated from 65° to 119° Fahr., a range of 54°, by the cooling of a mass of iron weighing 60 pounds, from an unknown temperature to 119° Fahr. The amount of heat communicated to the water was $50 \times 54 =$ 2 700 thermal units. Each pound of iron, therefore, parted with $\frac{2\ 700}{60} = 45$ units of heat.

The specific heat of iron is given by Watts as 0.112. It requires, therefore, the cooling of one pound of iron through 9° of temperature to heat a pound of water one degree. The iron, in the case considered, must therefore have lost $45 \times 9 = 405°$, when cooled to 119°, and its original temperature, and that of the escaping gases in the flue, must have been $405° + 119 = 524°$. The second observation, in a similar manner, gives the temperature of the chimney flue at 564.5°.

Watts gives 315° Centigrade, 599° Fahr., as a proper temperature with natural draft. Rankine gives absolute temperature of external air multiplied by $\frac{25}{12}$ as the temperature giving most effective draught. In this case, therefore, in which the average temperature of the air was 74°, the best temperature of chimney would have been $\left(25 \frac{74+461}{12}\right) - 461 =$ 6.45°.

(*To be Continued.*)

THE HELICAL PUMP.

BY MR. JOHN IMRAY.

From "Engineering."

In this paper the author described the helical pump patented in 1868 by Messrs. Boulton & Imray, and which consists of a paddle wheel revolving between two helical shells, from each of which there is a tangential passage of area equal to that of the wheel blade. When the wheel is caused to revolve in one direction a stream of water enters by one of these tangential passages, is carried round by the wheel becoming gradually shunted across the blades, and issues by the other tangential passage. When the direction of rotation is reversed the direction of the fluid stream is also reversed. The water in its movement through the pump forms, as it were, a liquid rope continually being wound on to the wheel barrel on the one side and payed out from it on the other side. In the passage of the liquid through the pump there are no abrupt bends or changes of direction, but only a simple circular sweep in the path of the wheel blades. Nor are there any changes in the form or area of the liquid stream. It is, therefore, believed that the loss from fluid friction occasioned by such changes of form, area, and direction in other rotary pumps is avoided in the helical pump. This pump can be used for pumping liquid in which solid matters are suspended, as in sewage, because any solid body having once entered by the inlet passage finds no impediment in its course to the outlet passage.

The pump maintains a head, without discharge, at a height twice that due to the velocity of the blades, but its efficiency is greatest when it discharges at half that height of head, that is, at the head due to the velocity. From numerous experiments the author stated that it had been found that there was a slip of about 15 per cent., or that a pump of such capacity, and working at such speed that it should discharge 100 gallons, if there were no slip, actually discharged about 85 gallons. He further observed that the work done by the pump in raising water, irrespective of the friction of the engine and pump itself, amounted to about 85 per cent. of the work done by the engine driving it, the loss of 15 per cent. being due to fluid friction. Taking into account the friction of the pump and of the engine driving it, the work actually realized was about 58 per cent. of the power applied. Many helical pumps are now at work raising considerable volumes of water, various heights from 10 feet to 40 feet; and the author stated that they were found particularly suitable for effecting circulation through surface condensers and refrigerators. The helical pump has been combined in a compact and simple manner with the elegant three-cylinder engine of Messrs. Brotherhood & Hardingham.

REPORTS OF ENGINEERING SOCIETIES.

The Society of Engineers.—At a recent meeting of the Society of Engineers (English), Mr. J. H. Adams, Vice-President, in the Chair, a paper was read on Tramway Rolling Stock and steam in connection therewith, by Mr. C. C. Cramp. The author reviewed all the leading historical events, extending over 100 years, connected with the use of steam on common roads and on tramways. The idea of steam-propelled carriages appears to have originated with Dr. Robinson, of Glasgow; but M. Cugnot was the first to put the idea into practice, which he did in 1770, by constructing a steam-moved carriage for the conveyance of artillery. In 1785, Murdock constructed a model steam carriage in England; and in the following year Oliver Evans experimented in the same direction in America, the legislature of Maryland granting him the right to use steam carriages and wagons in 1787. In the same year William Symington constructed a model steam carriage, and afterwards proceeded to carry out his system in practice, but did not succeed. Messrs. Trevithick and Vivian, however, were more successful; they constructed a steam carriage which ran for some time in London at the rate of nine miles an hour. Later on they took an improved tramway locomotive to George Stephenson at the Wylam Colliery. Then followed Brunton, Burstall, and Hill, Gordon, Gurney, Brown, all of whom experimented with various degrees of success; Gurney, however, running a steam coach for a long time at Bath at a speed of about twenty miles an hour. In 1829, Sir James Anderson and Mr. James ran a steam carriage with success for a time. Mr. Walter Hancock was the next to give effect to the idea of steam carriages on common roads, and he in 1831 ran a steam coach, the "Infant," regularly between Stratford and London with passengers. This coach used also to run to Brighton, and Mr. Hancock built several other steam coaches upon the same plan with success. Mr. Hancock appears to have done more than any other inventor to demonstrate the practicability of steam locomotion upon our highways, for in 1836 he put all his steam carriages on the Paddington Road, and ran them daily for about six months. Among others who took a prominent part in developing this question in England were Sir Charles Dance, Colonel Maccrone, Mr. Scott Russell (who, in 1834, established a line of steam coaches between Glasgow and Paisley), Dr. Church, Messrs. Maudslay, Fraser, Thompson, Nairn, E. Lamm, and L. J. Todd; whilst in America, Messrs. H. Dyer, J. Dixon, J. K. Fisher, A. B. Latta, J. D. Lake, Grice and Long, and G. F. Train, have all worked in the same direction. The late Mr. Grantham brought out the most recent example of a steam-moved tram car in England, and which has been the subject of very recent experiment with the view—when legislative enactment shall permit—of its introduction upon our Metropolitan Tramways. The author described the arrangements adopted by each inventor introduced in his Paper, and concluded by describing a tramway locomotive and a carriage designed by himself, as well as a brake and an apparatus for clearing the grooves of tramrails from an accumulation of mud or snow.

—*Architect.*

Manchester Scientific and Mechanical Society.—The second ordinary meeting of the members of the above association for the present session was held at their rooms in Mosley Street, the president, Mr. J. G. Lynde, occupying the chair. Mr. A. Hildebrandt, the honorary secretary, drew the attention of the members to the desirability of having some memorial of their late president, Sir William Fairbairn. He thought it would be a very fitting thing, and at the same time a movement which would be very beneficial to the society itself, if the members would subscribe to a fund, the interest of which would go to the establishment of a prize to be awarded for the best paper read during the session, which might be called the Fairbairn prize. Mr. Allott thought it was possible, if it was only to end in a bronze medal. After some further discussion it was resolved that the matter be referred to the Council. An adjourned discussion on a paper read by Mr. Evan Leigh at a previous meeting, on the waste of power in cotton mills, was then resumed, in which the members spoke in favor of applying power in all kinds of works direct from a drum on the shaft to the machinery by means of a belt, in preference to the old system of gearing. An animated discussion on the width, length and speed of running belts followed, and Mr. Leigh urged that five thousand feet a minute was a speed now quite practicable with the improved manufacture of belts. Mr. Gadd observed that an advantage was to be gained in new belts by reversing them on the drums. Mr. Evan Leigh remarked that this was because the smooth side allowed less air to get between the belt and the pulley and thus there was a better grip. Mr. Simpson, after giving an instance of the advantage of direct belt-driving, said there might be a temporary advantage in reversing a new belt, but when a new belt had got into proper working order he did not think there was much advantage to be gained. With regard to the length of belts it was urged that it was not desirable to have very great distances between the centres unless the drums were of large diameter, as the vibration would otherwise have an injurious effect upon the journals of the pulleys. After some further discussion with regard to the manufacture of special belts, the proceedings came to a close.—*Engineer.*

IRON AND STEEL NOTES.

Siberian Iron Market.—A correspondent of the *Daily News*, in describing the great fair of Nijni-Novgorod, gives the following valuable account of the iron mart in that celebrated emporium:

Iron, he says, has dethroned tea in its relative importance at Nijni. Whatever, too, may be the changes and vicissitudes in store for Nijni, it will probably remain the great depot for Siberian iron. Its position with reference to the river system of Russia will doubtless secure for it, permanently, this advantage. The railways of which we hear so much, as destined to revolutionize the trade in Nijni, will not, at any rate, affect it in the matter of iron. The difference in cost for the conveyance of heavy goods by water as compared with the cheapest rates of railway freight is 1.5. Indeed, the danger to Nijni in this respect comes from the river and not from the rail. Yaroslaf threatens Nijni as a depot, for that portion of the Siberian iron which goes to Moscow, just because the iron can travel as far as Yaroslaf by water, and from Yaroslaf to Moscow the distance is only 250 verts, by rail, as compared with 410 from Nijni to Moscow. Six million poods (about 3 1-10th poods are 1 cwt.) of iron of the value of eight-and-a-half millions of roubles are annually brought to Nijni. It comes from the neighborhood of Perm, brought down by the rivers Tschousowaya and Biclaya (which run into the Kama), by means of boats, specially built for this purpose, called "kolomenkas."

The chief mining districts are Nijni-Tajilsk, Wotkinskii, and Tjewskii; Demidof and Yarkowlew are the great iron proprietors in these parts. The price of iron fluctuates a great deal—from 1 rouble 10 copecks to 2 roubles 80 copecks a pood. The chief reason of this is that the trade is in the hands of a very few merchants who are able, by buying up all the iron from Demidof and Yarkowlew, to rig the market at their pleasure. The custom of the trade, which requires half the price to be paid down at purchase (the rest at twelve months' credit), tends to keep the trade in the hands of a small number of merchants with sufficient capital for it.

In 1866, two merchants, Roukawischnikow and Pastoukhow, bought up all the iron at Nijni, and sold it at a profit of 20 per cent. higher than its normal price. The Swedish and English iron, however, which are imported in considerable quantities to St. Petersburg, compete with, and tend to keep down, the price of the Oural iron. This latter, however, is considered to be of a superior quality; its reputed greater malleability is an important element in its value, especially in bridge making and other engineering operations. At Riga, too, the Oural iron meets the English and Swedish iron, and, from the length of time it takes in reaching Riga, is being driven out of the market by them. At Kief, too, another great centre of the iron trade, the foreign iron imported through Odessa is, in spite of its inferior quality, driving out the Oural iron. It has many advantages over this latter. In the first place the carriage from Odessa up the Dnieper is far easier than that from Nijni. This latter route is first to Kalouga by the Oka, then overland to Breanska, then by the rivers Desna and Dnieper to Kief, where goods from Nijni only arrive the following year; in the next place, the Odessa corn ships can afford to carry the iron at the cheapest possible rate as an alternative to returning to Odessa in ballast.

—*Iron.*

The *Chemical News* gives an analysis of some Heaton metal which is interesting. The metal question was from the sides of the reheating furnace used in preparing for the tilt-hammer the steel obtained by Heaton's process-action of Chili saltpetre upon fuzed cast iron. It was almost as white and lustrous as silver, showed little tendency to rust, and presented a remarkable appearance as of crystallization, the mass being made up of granules ranging from an eighth to a quarter of an inch in diameter, on which faces suggesting those of the octahedron and dodecahedron were everywhere observable. These faces, however, were nearly all of them more or less curved and contorted, and more careful examination seemed to show that the structure was in reality pseudo-crystalline only, as in the well-known cases of basalt, starch, etc. The mass would not bear much hammering without crumbling apart, the granules in question parting from one another without much difficulty, but each single granule proved to be tough and malleable, admitting of being flattened out easily enough upon the anvil. The iron could, moreover, be easily filed and sawed, and was not materially hardened by heating red-hot and suddenly cooling in water. It was, therefore, essentially wrought iron, sp. gr. = 7.86. After a careful qualitative analysis, Mr. Cabell obtained the following quantitative results: Carbon, 1.121; silicon, 0.024; sulphur, 0.037; phosphorus, 0.436; iron by difference, 98.382; total, 100.00. The large amounts of carbon and phosphorus are quite remarkable in connection with the malleability and incapability of being hardened of the metal, and its high specific gravity and curious structural character still further render it worthy of notice.—*Engineer.*

RAILWAY NOTES.

New Phosphor-Bronzes.—Dr. Kunzel, whose name will be recalled as the joint discoverer, with M. Montefiore-Levy, of the well-known phosphor-bronze, now announces the additional discovery that, when phosphor-bronze is combined with a certain fixed proportion of lead, the phosphorized tripple alloy, when cast into a bar or bearing, segregates into two distinct alloys, one of which is hard and tough phosphor-bronze, containing but little lead, and the other a much softer alloy, consisting chiefly of lead, with a small proportion of tin and traces of copper. The latter alloy is almost white, and when the casting is fractured, it will be found nearly equally diffused through it; the phosphor-bronze alloy forming, as it were, a species of metallic sponge, all of whose cavities are occupied by the soft metal alloy segregated from it. This phenomenon of the segregation into two or more alloys of combinations of copper with tin and zinc has long been known, and from the fact that such separation is generally massive, and not equable throughout the mass, it has been a source of great annoyance to the founder. Dr. Kunzel, however, seems to have succeeded in causing the segregation to take place in uniform distribution throughout the casting, and has taken advantage of the properties of the product which he obtains in this manner, to construct therefrom bearings of railway and other machinery.

In heavy bearings, such as those for marine engines, the valuable properties of Babbitt metal, and similar anti-friction alloys, are well recognized; but, these being generally soft, are open to the grave objection that where they are subjected to considerable pressure, or even moderate pressure, accompanied by continued vibration, they become distorted in form, and then fail to sustain the journals in their proper places. The device is, therefore, resorted to by the machinist, of casting a hollow cage of hard metal, of proper form, for the intended bearing, the cavities of which he then fills up by casting into them the soft metal alloy, which thus forms the actual rubbing surface of the bearing. The hard metal cage thus supports the metal within, and prevents its distortion or escape save by surface abrasion. Dr. Kunzel claims to effect the same result by the peculiar constitution of his new phosphorized alloy for bearings. This forms its own supporting cage, for the soft bearing metal, which, as alluded to at the outset, separates from it in the process of cooling. He claims that these bearings combine the very small friction and non-abrasion of the journals with the firm resistance to pressure and stability of form of bearings of hard metals. The test of practice, however, alone can decide the value of these claims, though they seem very plausible.

Steel Direct From the Ore.—The system Ponsard, for producing steel direct from iron ore, has attracted much attention, and *La Metallurgie* gives the following account of an experiment made on this system.

For several years metallurgists have essayed to treat iron ores in a reverberatory furnace, instead of the blast furnace, which, besides being very costly, can only, as yet, be worked with coke or charcoal, of which the cost has largely increased of late years. All the attempts made in Europe and America have heretofore been unsatisfactory, but the problem has at last been solved.

On the 27th of September, at the forge of the Verrieres, Vienne, France, the first production of pig iron by the direct treatment of the ore in the gas reverberatory furnace, system Ponsard, took place under the superintendence of the inventor, with the assistance of M. S. Perisse, director of the General Metallurgical Society of Paris.

The apparatus, which has formerly been described, consists principally of a gazogene, which transforms the fuel in a series of large chambers, and of an apparatus in brick, called the recuperator of heat, which receives the flames from the furnace, and restores the caloric in the form of hot air. The compartments of the chamber serve successively for the reduction of the ore, for the reactions which are effected, and, finally, for the fusion of the whole charge in such a manner that the separation of the component parts is effected by the difference of density. These various phases of the operation require very different temperatures, and the production of these is the special object of the apparatus. On the side of the furnace doors the temperature is only that of red heat, while beyond the heat is so great that the eye is unable to support the intensity of the glow. This extraordinary heat is estimated at 2,000 degree Cent.

The success of the experiment is reported to have surpassed all expectation, and the result obtained is considered to demonstrate the possibility of producing steel direct from the ore without any of the transformation necessary under existing systems. Of course this is a fresh revolution in the history of metallurgical industry; and it is almost unnecessary to add that, should the system justify the report, it will prove a revolution indeed.

Suspended Railway Carriages.—The French scientific journals report trials of a suspended railway carriage body on the Lille and Valenciennes Railway. The invention is by M. Giffard, the inventor of the injector. The body of the carriage is suspended by means of horizontal springs attached to brackets on the frame. These springs are made to work with great smoothness by the interposition of small bronze friction rollers between the several leaves of the spring, so that when a heavy shock occurs the plates move over each other without touching and with an easy rolling motion. This is the first time, it is said, that friction rollers have been introduced between the plates of springs. The reports on these new suspended carriages are favorable; the effect of sudden shocks and the unpleasant zig-zag movements are entirely obviated, or rather they are converted into different motions of a much milder description. The new carriages, in fact, when any disturbing cause appears, have the pitching and rolling motions of a vessel at sea, but to a very slight extent; enough, however, to be disagreeable to those who suffer much from such motions. On the whole, M. Giffard is considered to have hit upon a happy idea, and he is not likely to abandon it, if he sees a chance of success. In addition to the comfort of passengers, there is another consideration, namely, the wear and tear of the rails caused by transverse oscillations, which have a tendency to wear the tires and flanges of the wheels, and to cause the rails to be pressed outward. It remains to be seen whether the suspension of a portion of the weight of the rolling stock will prevent this destructive action.—*English Mechanic.*

RAILROADS IN ASIA MINOR.—Fifty miles of new railway are to be made forthwith in Asia Minor. This will constitute an extension of the Smyrna and Cassaba line. As far back as 1868, negotiations were entered into with the Government for the extension of the line to Alasheir, in view of its ultimate protraction along the valley of the Meander to Ouchak, and thence to Kutayeh, where it would join the great projected trunk line which is one day to connect Constantinople with the head of the Persian Gulf. It was, however, only eighteen months ago that an arrangement was come to with the Government for carrying the line further inland, and the Government then agreed to construct the line at its own cost, and to give the working of it, on certain conditions, to the Smyrna and Cassaba Company. A contract for the works was entered into with Mr. Samuel Bayliss, C. E., who resigned his post as general manager of the Smyrna and Cassaba line, in order to apply himself to the execution of his contract. That the contract was placed in good hands seems to be shown by the promptitude with which the works have been completed, and by the satisfactory report of the commission which has just returned from inspecting them. The extension has not, however, as yet been opened for traffic, although everything is ready, even to the printing of the tickets, for so doing. Some inexplicable hitch has apparently taken place with regard to the arrangements for working the line, and Edhem Pasha, under whose auspices it was expected that the ceremony of opening would take place, has returned to Constantinople, leaving the line unopened and local commerce in a state of discontent at the delay. The situation, however, seems too absurd for the possibility of its prolongation to be entertained. The extension, although reaching onwards towards Ouchak, the great centre of the internal trade of the valley of the Meander, does not even yet go near enough to it to admit of the full realization of the primary objects of the line. But it seems probable that it will—at all events it is possible that it may—open out a very important mining country, which would give the Alasheir line to Smyrna—with the help of a small branch or two—a very heavy mineral traffic. The Bozdagh range, which the line skirts all the way from Cassaba to Alashier, is full of coal, iron, copper, silver, lead, and other valuable ores, and several concessions have been applied for the purpose of working them.—*Engineer.*

ENGINEERING STRUCTURES.

WATER SUPPLY AND SEWERS OF PARIS.—The water service and the sewers of Paris have been, and still are, under the direction of M. Belgrand, Inspector-General of Ponts et Chaussées, and member of the Academy of Sciences. The sum required for the water service next year is, according to the *Society of Arts' Journal*, equal to £250,049, being £9,600 less that the expense in the current year.

The potable water of Paris is derived from the Seine and two other sources, while the watering of the streets, the supply of the public fountains, and the general cleansing, are effected by means of the waters of the Ourc, which are totally unfit for drinking or cooking. Another source is that of the artesian wells, but their cost is found to be so great that their further adoption is questionable. There are, however, at present in hand one at the Place Hebert, another at La Chapelle, and the third at the Butte-aux-Cailles.

The two sources of pure water for the use of Paris are those of the little streams of the valleys of the Dhuys and of the Vanne. The waters of the former have now for some years been received in an enormous reservoir, and the canal and reservoir of the Vanne are approaching completion.

The reservoir of the Vanne at Mont Souris, just completed, is an enormous structure of two stages, arched over and covered with turf. The cost of these canals and reservoirs has been very large, but the water supply brings in a considerable revenue, and will shortly bring in more. The income from subscriptions within the city, and from a company formed to supply water in the communes without the wells, is estimated to produce £280,000 in 1875, while certain other items add £20,000 more to the amount, and gradually, as the supply of water to the houses becomes general, and as cesspools give way to water-closets in connection with the sewers, the income from this source will increase largely.

Much more remains to be done before the system of sewers is complete. The great *egout collecteur*, or main sewer, was one of the sights of the Empire, and the work has been pursued, though not continuously, for twenty years. Still many small streets in the old parts of Paris have no connection with the new system of sewers, and most of the secondary streets of the suburbs have no other sewer but the gutter. Each year adds some miles to the length of the sewers, but the work cannot at present be pushed on rapidly on account of the heavy demands on the finances of the city. The budget for the coming year includes no important sewer work, but the sum required for the maintenance of existing sewers is £100,000. This also includes the maintenance of a small stream, which curiously corresponds to the Fleet in London, namely, the Bievre, which, has been converted into a sewer. The products which do not find their way into the sewers are carried away to La Villette and Bondy, and, with payments on account of public and private sewers, etc., produce £50,000. This service includes also the application of a considerable amount of the sewage of Paris to the cultivation of the market gardens of the plain of Gennevilliers.—*Builder.*

THE ST. GOTHARD TUNNEL.—The following progress was made at the St. Gothard Tunnel during the month of August: North side (Goeschenan), 120.40 metres; South side (Airolo), 60.68 metres; total advancement, 181.000 metres. The position of these works on the 31st of August was as follows: North side (Goeschenan), 1,246.20 metres; South side (Airolo), 1,048.60 metres; total length driven, 2,294.80 metres.

THE DRAINAGE OF ST. PETERSBURG.—The present municipality of St. Petersburg are not unmindful of the sanitary arrangements of their fine northern city. It is a known fact that, as far as drainage is concerned, St. Petersburg is one of the most backward towns of Europe. Several plans have been proposed for removing the sewage beyond the circuit of the town, both on the hydraulic and pneumatic system, but nothing has been definitely settled owing to the magnitude of the undertaking, and the difficulties which are likely to be met with on such a swampy soil as that upon which St. Petersburg is built. The existing waterworks are to be extended, and new waterworks to be erected in the important section of the town of Vasilyefsky Ostrof, on the right bank of the Neva, and for supplying also the districts of Peterburgskaya and Viburgskaya. Several of the smaller towns of the interior are following in the wake of St. Petersburg in this regard.—*Engineer.*

THE PERA AND GALATA TUNNEL AT CONSTANTINOPLE.—The works of this enterprise are fast assuming form, and at the terminal stations, Teké, for Pera, and Rue Yeni-Djami, for Galata, as also in the tunnel itself, every indication is now apparent of the "Metropolitan Railway" soon becoming an accomplishedfact, and carrying to and fro constantly during the day its freights of passengers and merchandise. A few days back a Ministerial party inspected the station at Galata and the railway carriages there, and then proceeded through the tunnel, brilliantly lighted on the occasion, where a trial was given to the steam-engines which turn the drum wheels winding the wire ropes by which the trains are pulled up and let down the rails. Edhem Pasha himself put the wheels in motion, and the apparatus worked with the most perfect ease and success, and almost noiselessly. The whole of this machinery has been constructed at the well-known Creuzot foundry in France. The members of the Board of Works then descended the tunnel to Galata, and, on leaving, warmly congratulated M. Gavand on the advanced stage of the undertaking. The stations are in course of completion, and the second line of rails within the tunnel is being laid. Within a month it is hoped the line will be in thorough working order and ready for public traffic. The diameter of the drum-wheels is so large that thirty turns will suffice to bring up a train from Galata to the Teké. Gas will not be employed in lighting the tunnel, for fear of accident. Oil lamps will be used; but the carriages themselves will be well lighted. A new street will run from the Grand Rue to the Teké terminus. A square will be formed between the Pera terminus and the monastery of the Dancing Dervishes, recently renovated and embellished, and omnibuses and hackney cabs will be stationed on this square for the convenience of passengers.
—*Builder.*

ORDNANCE AND NAVAL.

PRESERVATION OF IRON SHIPS.—A few months ago, 22d of May, we summarized the instructions issued by the Admiralty relative to the preservation of boilers by the placing of unslaked lime in those boilers which could be kept empty, and in those cases where they were liable to leakage from the sea, by filling them with a solution of lime in sea water. The result of the experimental application of the solution of lime has been so satisfactory that its use is to be extended to iron and composite ships under the circumstances described in the following circular, No. 36 of 1874, lately issued by the Admiralty: "Experiments having shown that the destructive action of bilge water on the iron frames, etc., of iron and of composite vessels may be reduced or altogether obviated by the use of lime, my Lords Commissioners of the Admiralty are pleased to direct that in all cases where it may be found impossible to dry out completely any of the compartments, bilges, or wings, in order to coat them with composition, paint, or cement, as prescribed by circulars 28 of 1872, 22 of 1873, and 31 of 1874, lime well slaked is to be placed in the water contained in such places. As unslaked lime would injure coatings of composition, paint, or cement, care is to be taken that the lime used is thoroughly slaked."
—*Engineering.*

A METHOD OF RAISING AND LOWERING THE SCREW OF A PROPELLER.—Mr. Harland, of Belfast, gave an account before the British Association of his method for raising and lowering the screw propeller in ships, remarking that during some voyages, and especially across the Atlantic, the wave line of the side of the ship was very often such as to leave an ordinary screw half exposed. Under these circumstances the engine has only half work to do, and consequently is apt to run off at such speed as to injure the machinery. To prevent this he has devised a simple method of lowering the screw, enabling the engineer in heavy weather to keep the vessel going much steadier, with very little reduced speed. A large amount of power was thus utilized, with the advantage of a uniform motion. In the normal position of the screw the tip should be in a line with the keel; but when the vessel is in more water than she really requires, the screw can be lowered, involving no change in the speed of the engine. To prevent the screw coming in contact with fishermen's nets, or other obstacles, a small shoe can be slipped under it if necessary. Mr. Harland's invention includes also a method of elevating the screw, to avoid contact with ice or other floating objects, and to enable it to be repaired without the necessity of actually taking the vessel into dock. The operation of raising and lowering the screw is readily and rapidly performed by means of a small engine on the deck. The invention of Mr. Harland was regarded by experts present at the meeting as being one of the most important ever introduced into steam navigation.—*Tribune.*

THE JAPANESE NAVY.—Japan has now altogether fifteen ships of war. A ram named the Adsumakan has engines of 500 horse-power and is armed with one 300-pounder and two 70-pounders, all muzzle loaders. The corvette Nitsinkan, of 1,000 tons burthen and 250 horse-power, is armed with a 7-inch Armstrong and six 60-pounders; her crew consists of 145 men. The Kagusakan has engines of 300 horse-power; she is armed with one 100-pounder, four 50-pounders, and one 20-pounder, and her crew consists of 130 men. The corvette Malacca (formerly English), of 1,400 tons burthen and 300 horse-power, is now called the Tukulakan, and she is being equipped as a training ship. Then Japan has four gunboats, the Wanyokan, the Mosikan, the Hoskolan, and the Thabarkan; they are armed with from four to six heavy guns each, and they have each crews of from 60 to 70 men. Japan has also some older gunboats, but they are regarded as practically useless for war purposes, and could only be used as hospital and store ships.

BOOK NOTICES.

Computation from Diagrams of Railway Earthwork. By Arthur M. Wellington, C. E. New York: D. Appleton & Co.

The calculation for earthwork of a long line of railway or canal is a weariness to the flesh; he who aids to lighten in any way the drudgery, without sacrificing accuracy, renders a substantial service to railway surveyors.

There are two methods of aiding the computer: One is to furnish him with tables in which the *quantities* for the more regular volumes have been carefully calculated, so that the bulk of his labor is reduced to finding products in an extended multiplication table; the other method furnishes the worker with diagrams in which the intersections of numbered lines indicate the required *quantities.*

Both methods have their advocates. Judging from the demand for *tables*, we estimate those who prefer to "see the figures" as constituting by far the majority. This is possibly owing to the limited application of the diagram methods that have been thus far offered.

Mr. Wellington's set of plates leaves nothing to be desired in this direction. We applied the tests suggested in the text, which fully describes the plan of construction of the plates, and became fully satisfied with the accuracy of the results.

On our own part, we could offer no objection to the use of the plates, save that they are exceedingly trying to the eyes. After an hour's work over them in a strong light, a badly stretched fish net seemed for a time to overlie the whole landscape. Aside from this inconvenience, which for many does not exist, Mr. Wellington's set of plates affords a very rapid method of obtaining accurate results in railway earthwork computation.

Les Torpilles. Par le Maj. H. De Sarrepont. Paris: J. Dumaine.

This is not so much a treatise on "torpedoes" as a collection of descriptive extracts, from a large variety of sources, of the torpedoes, existing and proposed, of all nations. The whole being taken from the "Journal des Sciences Militaire."

Course on Descriptive Geometry, for the Use of Colleges and Scientific Schools, by Professor Watson (Longmans, Green & Co.), is a very good textbook of the science of descriptive geometry. An appendix is added containing stereoscopic views of the solutions in space of the principal problems.—*Building News.*

Mechanics' Geometry. By Robert Riddell (London: G. Rivers), is by the well-known author of a treatise on staircase construction which we, some years since, reproduced. The work is designed to teach the carpenter and joiner, the mason, or metal-worker, or any other artisan, the knowledge of the constructive principles of his calling. To secure this end, the illustrations given are not mere surface diagrams, but actual models in cardboard of the figures represented, by means of which the student can be shown the lines brought together in actual projection, and thus be made more readily to understand the geometric plan the parts will cover when laid back upon the level surface of the illustration.—*Building News.*

Commercial Shorthand in Twelve Easy Lessons, arranged so as to be Learned without the Aid of a Master. By G. H. Willis. London: Elliott Stock.

The system of shorthand here introduced by Mr. Willis is based upon one which is perhaps the most generally known, that which has been so extensively popularized by Odell. Many of the most useful improvements of Pitman and others are, however, added, and a great number of useful and distinct stenograms and phraseograms—the latter both in roman and shorthand characters—are given, which are calculated considerably to abridge the labor of note-taking. The objections to Pitman's system, as one for merely occasional use, adduced by the author, are well-founded; the "light and heavy strokes, almost impracticable sections of the circle," the difficulty of acquiring it at first, and the immense practice necessary to retain it, make it unsuitable for clerks and others who do not require to use shorthand continually; while the distinctness and legibility of the present system, the ease with which the characters may be performed and retained in the memory, and with which they are distinguishable from one another, making the writing thus easy to read, combined with the amount of alphabetical condensation it affords, render it the very thing, not only for commercial people, but for clergymen, barristers, and professional persons of all kinds.

An Elementary Exposition of the Doctrine of Energy. By D. Heath, M. A. London: Longmans. 1874.

The fundamental principles in physics comprised in the above phrase, form an essential part of many modern theories of great importance which cannot be fully understood without reference to these. Mr. Heath's treatise is the substance of a course of lectures given to the highest form of a county school, and they have been published in their present form by the advice of the Government Examiner and other qualified persons who have detected their value. The result has been a little handbook which, from its clearness as well as completeness, seems well fitted for the use of the private student, or as a text-book for the higher classes in schools, for both of which purposes special pains have been taken to adapt it.

Practical Solid Geometry, or Orthographic and Isometric Projection. By J. Payne. London: Thomas Murby. 1874.

We were gravely told by the Gresham Lecturer, on Geometry the other night, as we sat almost freezing among his scanty audience, that the chief use of projection was to discover the relations existing between the circle and the ellipse. A statement like this is enough to make us wonder whether that lecturer knows anything at all about the practical application of the science he is supposed to teach. The twenty years' work of the Science and Art Department, to say nothing of the long practice of the drawing office, and the hundreds of books, elementary and profound, on the subject, afford an illustration of the true state of the case which is far more emphatic than all the lectures of all the Greshamites. The publisher of this little book might very well send a copy to Gresham College Library, where we will undertake to say it will be securely taken care of, though no man on earth could guarantee that the next lecturer on geometry would condescend to consult its useful pages. Mr. Payne has done his work well on the whole, though we are by no means convinced of the advisability of including an elementary and an advanced treatise within the same volume, especially when, as in this case, the elementary part suffers somewhat by the practice. The book belongs to a series intended to prepare for the South Kensington examinations, and Mr. Murby has furnished it with engravings somewhat better executed than those in others of the series.—*Iron.*

GRAPHICAL METHOD FOR THE ANALYSIS OF BRIDGE TRUSSES. By CHAS. E. GREENE, A. M. New York: D. Van Nostrand.

The Graphical Method is certainly growing in favor. The combined advantages of ease of application, sufficient accuracy, and ready detection of accidental errors, are enough to ensure its ready acceptance by a numerous class of engineers. To many able, practical men, the graphical is the only satisfactory method.

The present work is not a rudimentary treatise, although it presents in a brief way the elements of the method. The object of the author has been to present the difficult problems of the Continuous Girder and the Draw Span, and bring them within reach of this method of solution. A valuable addition is thus made to engineering literature, and a substantial service is rendered to the profession.

The separate chapters bear titles as follows:—Chaper 1, Single Span Trusses, with Horizontal Chords; Chapter 2, Single Span Trusses, with Inclined Chords; Chapter 3, Continuous Girder of two Spans; Chapter 4, Continuous Girder of Many Spans; Chapter 5, Pivot Bridges or Draw Spans.

Three folding plates illustrate the text.

OUTLINES OF PROXIMATE ORGANIC ANALYSIS. By Prof. ALBERT B. PRESCOTT. Price $1.75. New York: D. Van Nostrand.

The author of this compact little volume is the Professor of Chemistry in the University of Michigan. The work was originally compiled for his own use in instruction.

The title sufficiently explains the design of the treatise; its scope may be inferred from the following extract from the table of contents: Preliminary Examinations; Solid Non-Volatile Acids, Solid Volatile Acids; Liquid Non-Volatile Acids; Liquid Volatile Acids; Fatty Acids, Liquid and Solid; Neutral Substances, Liquid or Fusible; Bases, Liquid and Solid; Glucorides, and other Solid Neutral Substances; Nitrogenous Neutral Bodies; Carbohydrates; Alcohols and their Products.

The book is exceedingly well printed; the chemical formulas are in heavy type, and the arrangement of paragraphs and sections altogether give the pages an inviting appearance.

MISCELLANEOUS.

MAGNETIC VARIATIONS ON THE EASTERN SHORE.—SEAFORD, DEL., *Sept.* 1, 1874.—*To the Editor of the Railroad Gazette:* I subjoin a list of "Magnetic Variations" furnished by the late Prof. Bache of the Coast Survey, and used in running the boundary line between the eastern shores of Maryland and Virginia, to which regions the variations refer. They are fully confirmed by the ancient land-survey records of this part of "the Eastern Shore," and by the observations of the present surveyors, who give the last variation in the list, that for 1874, of 3° 30′. It is the fullest and best authenticated record with which I am acquainted bearing on this subject, and I have thought it might possess an interest for some of your readers.

S.

Variation of Magnetic Needle on the Southern Boundary of the Eastern Shore of Maryland.

1668	variation =	4°54′	West.
1680	"	" 5°06′	"
1690	"	" 5°06′	"
1700	"	" 4°54′	"
1710	"	" 4°36′	"
1720	"	" 4°06′	"
1730	"	" 3°30′	"
1740	"	" 42°5′	"
1750	"	" 2°18′	"
1760	"	" 1°42′	"
1770	"	" 1°06′	"
1780	"	" 0°42′	"
1790	"	" 0°24′	"
1800	"	" 0°18′	"
1810	"	" 0°18′	"
1820	"	" 0°30′	"
1830	"	" 0°48′	"
1840	"	" 1°18′	"
1850	"	" 1°54′	"
1860	"	" 2°30′	"
1870	"	" 3°15′	"
1874	"	" 3°30′	"

RESEARCHES ON EXPLOSIVES.—FIRED GUNPOWDER.—Captain Noble and Mr. Abel have come to a definite stage with their experimental researches into the action of fired gunpowder, and have embodied their conclusions in a report in the proceedings of the Royal Society.

Their objects they state to have been: 1—(1) To ascertain the products of explosion when fired in guns and mines; (2) to investigate the tension; (3) the effect of various sizes of grain; (4) the variation caused by various conditions of pressure, comparing explosion in a closed vessel with that in the bore of a gun; (5) the volume of permanent gas; (6) the heat; (7) to ascertain the work performed on a shot in the bore of a gun. For this very careful experiments were carried out to ascertain the pressure, volume of permanent gas, heat, and analysis of gases and solid products. A vessel of mild steel, tempered in oil, was used, completely closed with a closely-fitting screw firing plug, through which were led circuit wires with fine platinum wire enclosed with mealed powder, which it fired when heated by the current of a Daniell battery. The results were briefly as follows: The pressure was registered by Captain Noble's crusher gauges at from 1 ton to 36 tons per square inch. The analysis of the gaseous products showed a regular change, due to variation in pressure, carbonic anhydride increasing, with a decrease in carbonic oxide as the pressure increased. The solid products were subject to greater and less regular variation; speaking generally, the chemical action is more complicated than has been supposed, and the old fundamental equations are found to represent it very imperfectly. More carbonic oxide and potassium carbonate, and less potassium sulphate than has been thought, is produced. Potassium sulphide is thought to be formed primarily, but eventually it is not present in any considerable quantity, having given place to potassium hyposulphite. The temperature of explosion is found by means of platinum wire or foil to be about 2,200 deg. C. About 35 per cent. of the heat generated is communicated to a small arm, and but 3 per cent. to an 18-ton gun. The products of explosion consist of about fifty-seven parts by weight of solid to forty-three of permanent gas. When the powder fills the space in which it is fired, the pressure is about 6,400 atmospheres, or 42 tons per square inch. The products of explosion generally are the same in a gun and in a completely closed vessel. The work on the projectile is due to the elastic pressure of the permanent gases.

These results have only been obtained by a long and laborious course of very carefully conducted experiments. They are very valuable, and such as but very few individuals have the means of carrying out. Those interested in the subject, therefore, owe much to Capt. Noble and Mr. Abel, and those who have under them carried out the investigation so thoroughly and with such ability.

OBITUARY.

Two active and valued members of the engineering profession, both of whom have afforded valuable material for our pages, have passed away with the year 1874.

Geo. H. Mann, fatally injured by a railway accident, died on the 11th of June.

Mr. Mann had for some time been a resident of New Haven. From the *Journal and Courier* of that city we take the following extract:

Mr. Mann was a native of Brooklyn, N. Y., where his parents now live. He was trained to his profession by the most thorough and severe course that this country affords, having been graduated first at the Brooklyn Polytechnic and subsequently, after a five years' course at the Rensselaer Polytechnic of Troy, where he was graduated with the highest honors in his class. Since his settlement in New Haven he has been rapidly advancing to the highest position among our engineers. For the first two years he was a member of the United States Engineer Corps, engaged here on the Coast Survey. Since then he has been employed by all real estate men in the city, and upon a large share of the city improvements. Only recently he finished the surveys and drew all the maps, profiles, sections and plans for the West River canal, and was about to superintend its construction. He had just been appointed Assistant Engineer over the new Quinnippiac Bridge, and was in every way on the high road to an extensive and valuable business when thus suddenly cut down. It was under his direction that the recent valuable surveys and changes in our harbor have been largely carried on, including the location of the channel and buoy reefs. As a workman he was wonderfully rapid and accurate, while the maps and plans in which were embodied the results of his surveys were models of delicate and beautiful delineation. In this department he had no rival. He was also much employed as an expert in disputed surveys, and his opinion in such cases was highly valued. He was a man of thorough and wide training outside of his specialty, being a practical chemist of no mean order and a good linguist.

John W. Murphy, of Philadelphia, died after a brief illness on the 27th of September.

Mr. Murphy has been one of the most active members of the profession. He was graduated at the Rensselaer Polytechnic Institute in 1848, at the age of 19. His unflagging industry at that time was the wonder of his classmates. In addition to the labor of completing his regular course, he successfully accomplished during the last year all the mathematical studies of the post-graduate course.

In 1849 he began engineering practice as assistant engineer of Eastern Division of the Erie Canal. In 1850 he designed a suspension bridge over the Mohawk. A vertical truss added to the structure to insure stiffness was original with Mr. Murphy.

From 1851 to 1853 he built levees along the Alabama River.

In 1854 he built as contractor a bridge over the Delaware, at Easton. While engaged in this work he was led to abandon the old plan of "false works" and adopt an entirely new one which proved remarkably successful, and has been employed frequently since when building over a troublesome current. He suspended his "false works" on wire ropes. Using one of the piers for an anchorage, he made his cables fast by means of fox-bolts; then upon the curve of the cables between the next two piers he erected a diagonal bracing made of planking, up to the chord line; the other extremity of the cables being carried on to an anchorage across another span.

In 1856 he devised the Murphy-Whipple plan of bridges, and erected several in different parts of the country. It was at this time that he insisted that tests of iron should be made with reference to the "limit of elasticity" quite as much as to ultimate strength.

Among his brilliant achievements in rapid, original work, a good example is afforded by a bridge built for the Government during the war; the object being to reopen a route for the army of Rosecrans across the Gauley in West Virginia. It was a rigid suspension truss of novel design, five hundred and twenty feet in length, of three spans, completed and tested on the twenty-third day from the drawing of its plans.

The roof of Fair buildings in Union Square, Philadelphia; the Aqueduct across the Wissaheekon, at Valley Green, and the new bridge at South Street, Philadelphia, are some of his more prominent later works.

He was a ready writer, a good speaker, and one of the most genial of companions. His contributions to engineering literature were numerous and valuable; they chiefly embodied discussions of accomplished works.

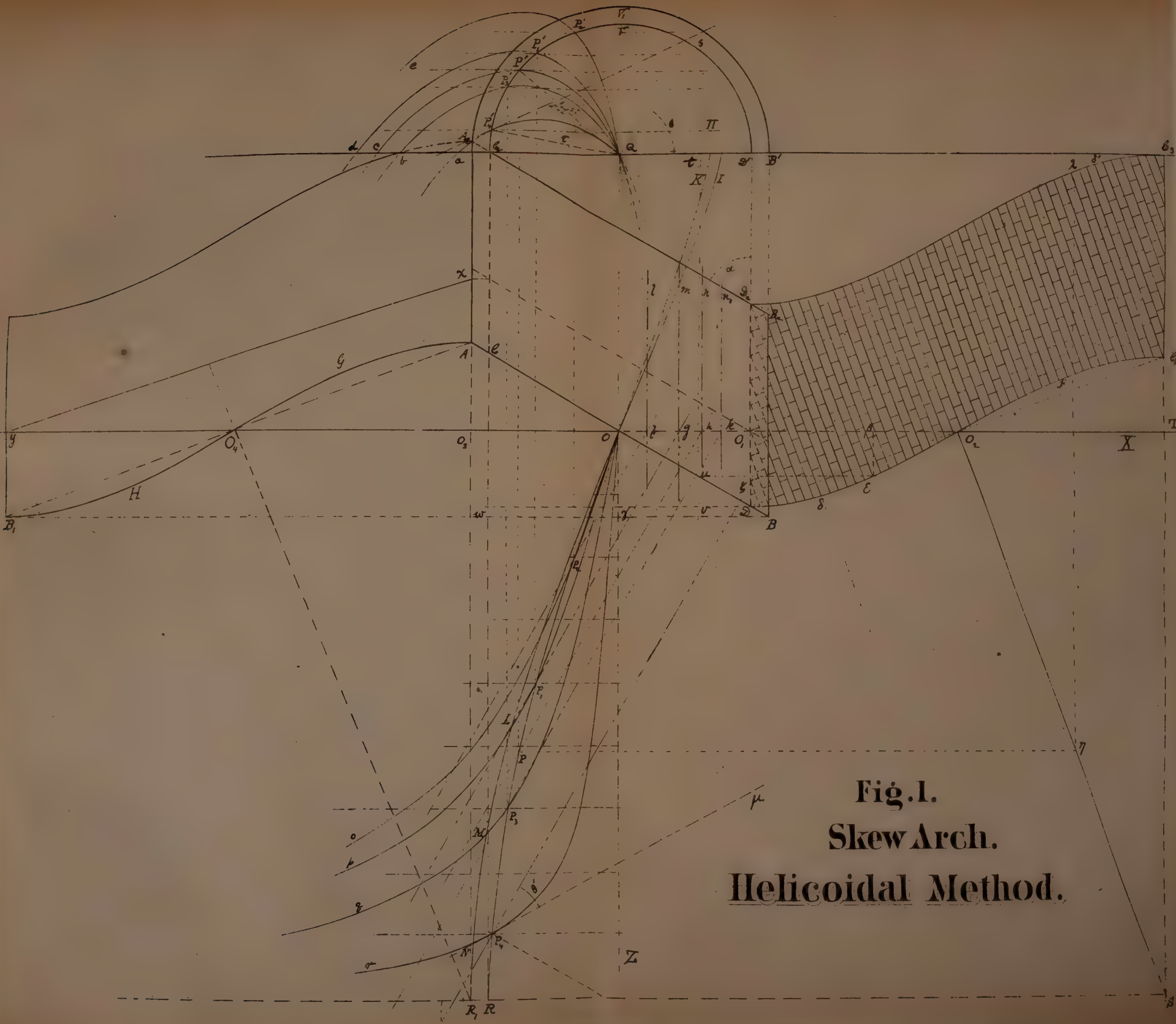


Fig. 1.
Skew Arch.
Helicoidal Method.

VAN NOSTRAND'S ECLECTIC ENGINEERING MAGAZINE.

NO. LXXIV.—FEBRUARY, 1875.—VOL. XII.

SKEW ARCHES.

I.

By E. W. HYDE, C. E

Written for VAN NOSTRAND'S MAGAZINE.

I PROPOSE in this paper to discuss to some extent three methods which have been employed in the construction of oblique or skew arches, and to make a comparison of their relative security, facility of construction, etc.

The three methods will be designated as,

1st. The Helicoidal method.
2d. The Logarithmic method.
3d. The "Corne de Vache" or Cow's-horn method.

The first two names are derived from the nature of the coursing and heading, joint surfaces and their intersections with the soffit, and the third from the soffit itself, which is a warped surface that has been thus named. They will be considered in the order given above.

The following abbreviations will be used throughout the paper:

C j c, for coursing joint curve, or intersection of coursing joint with soffit.
H j c, for heading joint curve.
C j s, for coursing joint surface.
H j s, for heading joint surface.
H P, for the horizontal plane of projection.
V P, for the vertical plane of projection.
P F, for the plane of the face of the arch.

Ex. s, for the extradosal or outer surface of the arch.

THE HELICOIDAL METHOD.

In this method the C j s's and H j s's are both warped helicoids, and of course their intersections with the soffit helices.

Let C D D_2 C_2 be the projection of the soffit on the H P which coincides with the springing plane of the arch, and D′ V C_1 is a semicircle whose radius will be designated by r.

The Ex. s will be taken as a concentric cylinder projected in A B B_2 H_2 and B′ V′ A_2 and its radius will be designated by r_1.

To construct the C and H j c's we will first develop the soffit. Lay off O_1 $T = \pi = 3{,}1416\ r$; the points of the curve D E F C_1 may be found by the principles of descriptive geometry or by means of the equation of the curve, which we shall obtain. The latter method is much more accurate for construction upon a large scale.

Let $h = D'D_2$, and σ = angle C_2D_2D' = obliquity of the arch; ∴ tang. $\sigma = \frac{2r}{h}$.

Also θ = variable angle sQD'. The origin will be taken first at O_1. We have from the figure

$O_1\,\beta = x = r\,\theta.$

$O\,x = \frac{1}{2}\,h,\ E\,\beta = -\,y.$

$$\therefore\ \frac{\frac{1}{2}h + y}{h} = \frac{r\,(1 - cos\ \theta)}{2r} = \frac{1 - cos\ \theta}{2}$$

$$\therefore\qquad 1 - cos\ \theta = \frac{h + 2y}{h}$$

$$\text{and}\qquad cos\ \theta = -\frac{2y}{h}$$

$$\therefore\qquad \theta = cos^{-1}\left(-\ _h\ \right)$$

$$\text{whence}\qquad x = r\ cos^{-1}\left(-\frac{2y}{h}\right).$$

Solving for y we have

$$(1)\qquad y = -\frac{h}{2}\ cos\ \frac{x}{r},$$

which is the equation of D E F C, with the origin at O_1. If the origin be moved to O_2 the equation becomes

$$(2)\qquad y = \frac{h}{2}\ sin\ \frac{x}{r}.$$

From either of these equations the values of y for given values of x may be easily obtained by the aid of a table of natural sines and cosines.

Having constructed the curve D E F C_1, join D and C_1 by a straight line. This will be the development of a H j c. At O_2 draw O_2 S perpendicular to D C_1. O_2 S is the development of $\frac{1}{4}$ of a spire of the helix which forms the C j c's, and corresponds to the curve O P R.

$$\text{The angle } TO_2S = TC_1O_2 = tang.^{-1}\ \frac{\pi r}{h}$$

$$\therefore TS = O_2T\ tang\ T\ O_2S = \frac{\pi^2 r^2}{2\,h} = \tfrac{1}{4}\,\pi^2\,r\,tan\ \alpha$$

Now divide D E F C_1 into a convenient odd number of equal parts, so arranging it as to cause one of the C j c's as δ D_2 to pass through D_2. The developments of the C j c's are of course drawn parallel to O_2 S through the points of division of the curve D E F C_1. If it were not convenient to divide D E F C_1 in such a manner that a line through D_2 parallel to O_2 S would exactly pass through one of the points of division, the direction of the C j c's might be slightly changed, or the divisions between D_2 δ and C_2 δ might be made very slightly larger or smaller, as the case required, then the divisions from D to δ and from C_3 to δ'. The latter method seems preferable, since it preserves the perpendicularity between the C and H j c's, and the difference in the size of the voussoirs would be so small as not to be noticeable.

All the courses below δ and δ_1 run out into the abutment, and the impost must be cut in steps, as shown in the figure, into which the voussoirs will fit.

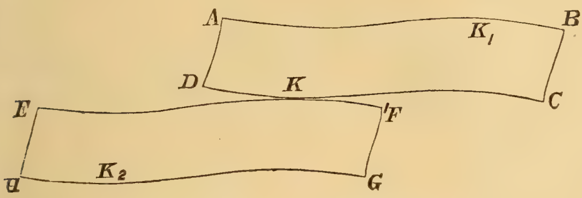
A G H B_1 is the development of the extrados, and the right line $x\ y$ that of a helix in which one of the H j s's intersects the Ex. s. O_4 R_1 is the development of the curve O L R_1, in which a C j s intersects the Ex. s.

$$Tan\ x\ y\ O_3 = \frac{h}{\pi r_1}.$$

$$Tan\ O_3\ O_4\ R_1 = \frac{T\,S}{\frac{1}{2}\,\pi\,r_1} = \frac{\pi^2\ r^2}{2h} \div \frac{\pi\,r_1}{2} = \frac{r}{r_1},\ \frac{\pi\,r}{h} = \frac{\pi\,r}{2\,r_1}\ tan\ \alpha.$$

The C j s's are generated by a right line moving on the axis O Q as one directrix, the helix O P R as a second, and remaining always perpendicular to the former. Hence the V P is a plane directer of the surface.

The details of the construction of a skew arch by this method are fully developed in "A Practical and Theoretical Essay on Oblique Bridges," by John Watson Buck, M. Inst. C. E. He, however, makes the C and H j s's *hyperbolic paraboloids* instead of helicoids, as follows: The corners of the voussoirs are normals to the soffit at the intersection of the H and C j c's, and hence are elements of the warped helicoids, which *should* form the H and C j s's. The points where two of the normals on the same side of the voussoir pierce the soffit are joined by a right line, and this line is moved on the normals as directrices in such a manner as to pass over equal distances, measured on the normals in equal times, by which operation a hyperbolic paraboloid is generated. The accompanying figure is an exaggerated representation of the effect of cutting the stones in this manner. A B C D and E F G H are the developed introdosal surfaces of two voussoirs in successive courses. If the courses were not required to break joints, the stones would fit perfectly, but as this is necessary to the stability of the arch, that portion of a stone which is too full will come opposite to the portion of the one in the next course which is likewise too full, and similarly the hollow portion of one opposite to the hollow portion of the next.



The truth of these statements will appear as follows: The hyperbolic paraboloid evidently cannot coincide with the helicoid, as they are surfaces constructed according to a different law. The normals to the two adjacent corners of a voussoir are elements of both surfaces. The normal midway between these two is also an element common to the two surfaces. Hence it is evident from the mode of their generation that the two surfaces intersect each other along each of these three lines. A section of the surfaces by a plane perpendicular to the middle normal would give something like the accompanying figure,  the straight line being the intersection with the hyperbolic paraboloid and the curve that with the helicoid.

However, if the voussoirs are small compared with the whole arch, as in Fig. 1, the difference between the paraboloidal and helicoidal surfaces in the length of one voussoir will be exceedingly small, and the stones will fit with sufficient exactness for practical purposes. Nevertheless, the *tendency* is to cause the pressure to be unequally distributed, concentrating it at K, K_1, K_2 and at A, C, E and G. The difficulty of cutting the warped faces of the voussoirs is considerably diminished by this approximate method.

An investigation will now be made of the security of an arch constructed according to the helicoidal method.

In order that there may be *no* tendency in the successive courses to slide upon each other, it is evident that each C j s must be at every point normal to the direction of the pressure at that point. We shall consider first the direction of pressure as regards its parallelism to a certain vertical plane, without reference to the angle it may make at any point with the H P. This vertical plane is the place of the face of the arch. It is probable that the direction of pressure varies somewhat with reference to this plane in different portions of the arch, especially if the crown settles to any extent after removal of the centre. Still it must be approximately parallel to the P F, otherwise the portions near B and A_2 would be unsupported and would consequently fall. For the purposes of the investigation then the direction of pressure will be *assumed* to be in a plane parallel to the P F, and from the results obtained we shall be able to see without difficulty the effect upon the security of the arch which would be produced if the direction of pressure were *not* parallel to the P F. Proceeding then on this assumption, a line drawn on the C j s of any voussoir and lying in a plane perpendicular to the P F and to the H P *ought* to be *horizontal*, but as this line would be the intersection of a warped helicoid by a plane not containing an element of the surface, it must be a *curve*, and can only be horizontal at a maximum or a minimum point, at infinity, or at some singular point. The intersection of the C j s of a voussoir by a *horizontal* plane should give a line perpendicular to the P F, but this line would be also a curve, and could have the required direction only at one or more points. It becomes necessary then to discover the nature of these curves and the direction of their tangents at the point of piercing the soffit.

In Fig. 1 (Frontispiece) the curves Q P'_4 *a*, Q P'_3 *b*, etc., are the vertical projections of the curves cut by the vertical planes, P_4 *g*, P_3 *k*, etc., from the helicoid whose directrices are the axis O Q and the helix O P R. The curve Q P′*c* has a maximum point at P P′ where it pierces the soffit; all those above it have a maximum point *outside* the soffit, and those below it have one *inside* the same.

The curves O P_4 *r*, O P_3 *q*, etc., are cut by horizontal planes through the points P_4 P'_4, P_3', etc. The curve through P is not drawn, but if it were it would be tangent at P to the line P *h*.

It is plain from inspection of these curves that the courses below P P′ have a tendency to slide upon each other in a direction from A_2 towards A, which increases as the abutment is approached. In Fig. 1 this point P P′ is on the tenth course from the abutment, and there are three coursing joints which would have a tendency to slide throughout their whole length with nothing to resist it except friction between the surfaces. The *partial* courses would be prevented from sliding by the steps cut in the impost. Above P P′ the tendency to slide would be in the opposite direction, but would be so small as not to affect seriously the stability of the arch. This will be evident from inspection of the curves O P_1 *p* and O P_2 *o*.

We will now investigate these curves analytically and determine the position of the point P P′.

The distance T S, Fig. 1, is ¼ the height of one spire of the helix O P R, and from eq. (3) $TS = \frac{^2\pi r^2,}{2h} = \frac{1}{4}\pi^2\ r\ tan\ \alpha.$

Call the height of one spire of the helix h_1, then

$$h_1 = \frac{2\pi^2 r^2}{h} = \pi^2 r\ tan\ \alpha.$$

Let O be the origin of coörds, the axis of the cylinder, O Q, the axis of Z, O T the axis of x, and the axis of y a vertical line through O. Then we shall have for the helix O P R.

$$\frac{\theta - \frac{\pi}{2}}{2\pi} = \frac{z}{h_1};$$

whence $\theta = \frac{2\pi z}{h_1} + \frac{\pi}{2}$.

Also

$$x = r\cos\theta = r\cos\left(\frac{2\pi z}{h_1} + \frac{\pi}{2}\right) = -r\sin\frac{2\pi z}{h_1},$$

or substituting for h, its value

$$(4) \qquad x = -r\sin\frac{hz}{\pi r^2}$$

which is the equation of O P R, the projection on X Z of one of the C j c's. The vertical projection, or the projection on X Y of this helix is

$$(5) \qquad x^2 \times y^2 = r^2.$$

To obtain the equation of the C j s, we must find the equations of an element, and then eliminate the constant which fixes its position. Let one equation of the element be

$$(6) \qquad z = z_1.$$

To find the equation in terms of x and y, substitute in the equation

$$\frac{y - y_1}{x - x_1} = \frac{y_1 - y_2}{x_1 - x_2}$$

of a line through two points the proper values of x_1, x_2, y_1 and y_2. We have since all the elements cut the axis of z,

$$x_1 = o \text{ and } y_1 = o.$$

Substituting from (6) in (4)

$$x_2 = -r\sin\frac{hz_1}{\pi r^2},$$

and substituting this value of x_2 in (5),

$$y_2 = \sqrt{r^2 - r^2\sin^2\frac{hz_1}{\pi r^2}} = r\sqrt{1 - \sin^2\frac{hz_1}{\pi r^2}}$$

$$= r\cos\frac{hz_1}{\pi r^2}.$$

$$\therefore \frac{y}{x} = -\frac{r\cos\frac{hz_1}{\pi r^2}}{r\sin\frac{hz_1}{\pi r^2}} = -\cot\frac{hz_1}{\pi r^2};$$

or making z_1 general by dropping the subscript,

$$(7) \qquad y = -x\cot\frac{hz}{\pi r^2},$$

which is the equation of a C j s.

Now, intersect this surface by a vertical plane perpendicular to the P F, whose equation is

$$(8) \qquad z = \frac{2r}{h}(a_1 - x),$$

in which a_1 is the intercept on X.

$$(9) \qquad \therefore y = -x\cot\left(\frac{2(a_1 - x)}{\pi r}\right)$$

which is the equation of the curves Q P′ *c*, etc.

In equation (9) if

$$x = o, \qquad y = o;$$

$$\text{if } x = a_1 - \frac{(2n-1)\pi^2 r}{4},$$

$$y = -x\cot\frac{(2n-1)\pi}{2} = 0,$$

n being an integer;

$$\text{if } x = a_1 - \frac{n\pi^2 r}{2},$$

$$y = -x\cot n\pi = \infty,$$

n as before being an integer. Hence the curve has an infinite number of branches. It is to be noticed that equation (9) *does not contain h*, the only constants being π, a_1 and r, *hence the form of the curves Q P' c, Q P'₁ d*, etc., *is entirely independent of the obliquity of the arch.* We will next differentiate equation (9) for a maximum.

$$\frac{dy}{dx} = -\cos\left(\frac{2(a_1-x)}{\pi r}\right) - \frac{2x}{\pi r \sin^2\left(\frac{2(a_1-x)}{\pi r}\right)}$$

Let $\frac{2(a_1 - x)}{\pi r} = u$

$$(10)\quad \therefore \frac{dy}{dx} = -\cot u - \frac{2x}{\pi r \sin^2 u}$$

For a maximum

$$\cot u = -\frac{2x}{\pi r \sin^2 u}.$$

$$(11)\ \therefore x_{ymax} = -\frac{\pi r \sin u \cos u}{2}.$$

By solving equation (11) the values of x for which y is a maximum or minimum can be obtained. It is only capable, however, of an approximate solution, but if we obtain the x co-ordinate of the intersection of the locus of equation (9) with the circle

$$(12)\qquad x^2 + y^2 = r_2^2,$$

in which r_2 may have any value, and place this value of x equal to that in equation (11), we shall obtain the value of x_{ymax} when the maximum point is at the intersection of the two curves.

$\therefore$ substituting from (9) in (12)

$$x_i^2 + x_i^2 \cot^2 u_i = r_2^2$$

$$x_i^2 (1 + \cot^2 u_i) = x_i^2 \operatorname{cosec}^2 u_i = r_2^2.$$

$$(13)\qquad \therefore x_i = r_2 \sin u_i.$$

$\therefore$ by (11) and (13),

$$r_2 \sin u_i = -\frac{\pi r \sin u_i \cos u_i}{2}$$

$$\therefore \cos u_i = -\frac{2 r_2}{\pi r}$$

$$\frac{2(a_1 - x_1)}{\pi r} = u_i = \cos^{-1}\left(-\frac{2 r_2}{\pi r}\right)$$

$$\therefore \psi_i = a_1 - \frac{\pi r}{2} \cos^{-1}\left(\frac{2 r_2}{\pi r}\right).$$

Denoting by x_{mi} the value of x for which y is a maximum when the locus of (9) is subject to the condition of having a maximum point at its intersection with $x^2 + y^2 = r_2^2$, and substituting the value of x just found in the 2d member of (13), we have

$$x_{mi} = r_2 \sin\left\{\frac{\left(2a_1 - a_1 + \frac{\pi r}{2}\cos^{-1}\left(-\frac{2r_2}{\pi r}\right)\right)}{\pi r}\right\}$$

$$= r_2 \sin \cos^{-1}\left(\frac{2 r_2}{\pi r}\right)$$

$$= r_2 \sin \sin^{-1} \sqrt{1 - \frac{4 r_2^2}{\pi^2 r^2}}$$

$$= r_2 \sqrt{\frac{\pi^2 r^2 - 4 r_2^2}{\pi^2 r^2}}$$

$$(14)\quad \therefore x_{mi} = r_2 \frac{\sqrt{\pi^2 r^2 - 4 r_2^2}}{\pi r}$$

Let $r_2 = r$, this being the condition that the maximum point shall be at the point where the locus of (9) pierces the soffit, and we have

$$(15)\quad x_{mi} = \frac{r}{\pi}\sqrt{\pi^2 - 4} = r \cos \tau.$$

Whence

$$(16)\ x_{mi} = 0.77118r = r \cos 39^\circ\, 32'\, 23''.$$

This value of τ may also be found by means of the curves OP_1p, OP_2o, etc. Intersect the surface of equation (7) by the horizontal plane

$$(17)\qquad y = b.$$

$$\therefore\ b = -x \cot \frac{hz}{\pi r^2}$$

$$(18)\quad \text{or}\quad x = -b \tan \frac{hz}{\pi r^2},$$

the equation of the curves OP_1p, etc.

Differentiating

$$(19)\quad \frac{dr}{dx} = -\frac{\pi r^2}{bh}\cos^2 \frac{hz}{\pi r^2}$$

If $z = \pm \frac{\pi^2 r^2}{2h}$ in (18) and (19) we have

$$x = \infty \text{ and } \frac{dr}{dx} = o,$$

showing that the lines $z = \pm \frac{\pi^2 r^2}{2h}$ are asymptotes of the curves.

Intersect the circle $x^2 + y^2 = r_2^2$ by $y = b$

$$\therefore\ x_i = \pm \sqrt{r_2^2 - b^2}.$$

Substitute this value of x in (18) and

$$\pm_1 \sqrt{{}_1r_2^2 - b^2} = -b \tan \frac{h z_i}{\pi r^2};\ \text{whence}$$

$$(20)\quad z_1 = \frac{\pi r^2}{h} \tan^{-1}\left(\frac{\mp \sqrt{r_2^2 - b^2}}{b}\right)$$

z_i is the z co-ordinate of the point in which the locus of (18) pierces the cylinder, concentric with the soffit, whose radius is r_2.

Substitute from (20) in (19), thus

$$\frac{dz_i}{dx_i} = -\frac{\pi r^2}{b h} \cos^2 \left\{ \tan^{-1} \left(\frac{\pm \sqrt{r_2^2 - b^2}}{b} \right) \right\}$$

$$= -\frac{\pi r^2}{b h} \left\{ \cos \cos^{-1} \frac{1}{\sqrt{1 + \frac{r_2^2 - b^2}{b^2}}} \right\}^2$$

$$(21) \qquad = -\frac{\pi b}{h} \left(\frac{r}{r_2} \right)^2$$

If $r_2 = r$, when the cylinder mentioned above becomes the soffit,

$$(22) \qquad \frac{dz_i}{dx_i} = -\frac{\pi b}{h},$$

which is the tangent of the angle between the tangent to the locus of (18) and the axis of x at the point where the locus pierces the soffit. If we make the condition that

$$(23) \qquad \frac{dz_i}{dx_i} = -\frac{2 r}{h};$$

that is, that the tangent at this point shall be perpendicular to the P F, we have from (22) and (23)

$$\frac{\pi b_1}{h} = \frac{2 r}{h}$$

$$(24) \therefore b_1 = \frac{2 r}{\pi} = 0.63662\, r = r \sin 39° \, 32' \, 23''$$

which agrees with equation (16).

It is thus apparent that in an arch constructed by this method the portions below PP′ or beyond the line $\eta\gamma$ on the development, should be *omitted; i.e.*, the arch should be *always segmental* with a span not exceeding $2 r \cos \tau = 2 r \cos 39° \; 32' \; 23'' = 1.54236 r$, provided that there is to be no tendency in the successive courses to slide on one another. The amount of this tendency to slide and its relation to the obliquity of the arch will next be investigated.

Let us obtain an expression for the angle $\mathcal{E}\, P_4\, \mu$ between the tangent line to O P_4 r at P_4 and the line $P_4\, \mathcal{E}$ perpendicular to the P F. Let $\mathcal{E}\, P_4\, \mu = \theta'$ then, equation (22),

$$\theta' = \tan^{-1} \frac{2 r}{h} - \tan^{-1} \frac{\pi b}{h}$$

(25)

$$\therefore \tan \theta' = \tan \left(\tan^{-1} \frac{2 r}{h} - \tan^{-1} \frac{\pi b}{h} \right) =$$

$$\frac{\frac{2 r}{h} - \frac{\pi b}{h}}{1 + \frac{2 \pi b r}{h^2}} = \frac{h (2 r - \pi b)}{h^2 + 2 \pi b r}$$

If $h = o$, $\tan \theta' = o$, $\therefore \theta' = o$.

If $h = \infty$ $\tan \theta' = o$, $\therefore \theta' = o$.

θ' must be equal to θ when $\tan \theta' = o$ because it can never equal, much less exceed 90°; for if it *can* equal 90°, then we must have from (25)

$$h^2 + 2 \pi b r = 0;$$

$$\therefore h = \sqrt{-2 \pi b r};$$

i. e., h must be imaginary. It follows that there must be some value of h for which tan θ' and therefore θ', is a maximum. By placing the first differential co-efficient of the function with reference to $h = s$, we find this value to be

$$(26) \qquad h = \sqrt{2 \pi b r}.$$

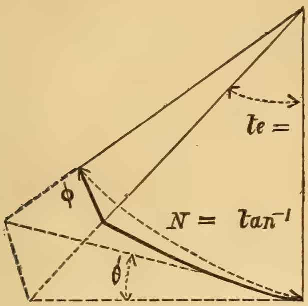
By this equation $h_{\theta' \max} = 2 r \cot \alpha_{\theta' \max} = 1.0445\, r$, when $b = r \sin 10°$ $\therefore$ $\alpha_{\theta' \max} = 62° \; 25'$ for this value of b.

Now the tendency to slide at any point, as P_4 P_4', depends upon the angle between the normal to the C j s at that point and the direction of the pressure. This last we have assumed to be in a plane parallel to the P F. We will now assume for the purposes of the investigation that it coincides at the point $P_4 P_4'$ with the direction of the tangent at that point to the ellipse cut from the soffit by a plane through the point parallel to the P F. Let p_1 = tangent of angle between ground line and tangent line to curve Q P_4' a at the point P_4'; then the tangent of the angle between the tan line to this curve in space at the point P_4 P_4' and the H P will be $= p_1 \cos \alpha$.

Let p_2 = tangent of angle between a vertical line and the tangent line to the circle D′ V C_2 at the point P_4' = angle P_4' Q C_2, then the tangent of the angle between a vertical and the tangent line at P_4 P_4' to the section of the soffit parallel to the P F will be $= p_2 \operatorname{cosec} \alpha$.

Now to find the angle between the normal at P_4 P_4' to the C j s, and the tangent to the section parallel to the P F, we have given two sides and the included angle of a spherical triangle, the included angle being θ'.

Let N = angle between normal to C j s, at P_4 P_4' and vertical = angle be-



-tween tangent plane to C j s at P_4 P_4' an H P, then we find the value of tan N to be tan N $= p_1 \cos \alpha \operatorname{cosec} \theta'$.

$$(27) \quad \therefore \sin N = \frac{p_1 \cos \alpha \operatorname{cosec} \theta'}{\sqrt{1 + p_1^2 \cos^2 \alpha \operatorname{cosec}_2 \theta'}}$$

$$(28) \quad \cos N = \frac{1}{\sqrt{1 + p_1^2 \cos^2 \alpha \operatorname{cosec}^2 \theta^1}}$$

and if $t_e = \tan^{-1}(p_2 \operatorname{cosec} \alpha)$, we have

$$(29) \quad \sin t_e = \frac{p_2 \operatorname{cosec} \alpha}{\sqrt{1 + p_2^2 \operatorname{cosec}^2 \alpha}}$$

$$(30) \quad \cos t_e = \frac{1}{\sqrt{1 + p_2^2 \operatorname{consec}^2 \alpha}}.$$

By spherical trigonometry

(31) $\cos \Phi = \cos N \cos t_e + \sin N \sin t_e \cos \theta'$; whence, by substitution

$$(32) \quad \cos \Phi = \frac{1 + p_1 p^2 \cot \alpha \cot \theta'}{\sqrt{(1 + p_1^2 \cos^2 \alpha \operatorname{cosec}^2 \theta')(1 + p_2^2 \operatorname{cosec}^2 \alpha)}}$$

Multiplying numerator and denominator by $\sin \alpha \sin \theta'$, this becomes

(33)

$$\cos \Phi = \frac{\sin \alpha \sin \theta' + p_1 p_2 \cos \alpha \cos \theta'}{\sqrt{(\sin^2 \theta' + p_1^2 \cos^2 \alpha)(p_2^2 + \sin^2 \alpha)}}$$

If in this equation $\alpha = o$, then by equation (25), since $h = 2 r \cot \alpha$, $\theta' = o$, and hence $\cos \Phi = \frac{p_1 p_2}{p_1 p_2} = 1$, $\therefore \Phi = o$.

If $\alpha = 90°$—*i.e.*, the obliquity=0—by (25) $\theta' = 0$, and hence $\cos \Phi = \frac{0}{0}$ indeterminate. The reason for this is, that the tangent lines to the curves ƨ P_4» $QP_4'a$, and OP_4r»$P'_4\pi$ by which we have fixed the position of the tangent plane *coincide* when $\alpha = 90°$. The value towards which $\cos \Phi$ *approaches*, however, is unity, as α approaches 90°, for from the relations between the quantities it is evident that when $\theta' = 0$, N must equal t_e, and hence by equation (31),

$\cos \Phi = \cos^2 t_e + \sin 2\, t_e = 1$; $\therefore \Phi = o$.

It follows, therefore, that there must be some value of α for which $\cos \Phi$ is a minimum, and therefore Φ a maximum, for any given values of p_1 and p_2. Owing to the complexity of the expression for $\cos \Phi$, this value would be very difficult to obtain by differentiation; but it can be determined approximately by calculating a series of values of $\cos \Phi$ for different values of α. This has been done, with the following results:

The point for which the calculations are made is P_4 P'_4, for which

$x = -r \cos 10°$, $y = b = r \sin 10°$, $z = \frac{4 \pi^2 r^2}{9 h}$ $p_2 = \tan 10°$, and $p_1 = 0.47011 = \tan 25° 10' 43''$, the value of p_1 being found by equation (10).

TABLE I.

When $\alpha = 60°$,	$\theta' = 34° 42' 41''$, and	$\Phi = 14° 57' 30''$
" $\alpha = 40°$,	$\theta' = 27° 10' 00''$, "	$\Phi = 25° 27' 00''$
" $\alpha = 30°$,	$\theta' = 21° 8' 00''$, "	$\Phi = 31° 00' 00''$
" $\alpha = 20°$,	$\theta' = 14° 19' 50''$, "	$\Phi = 34° 44' 00''$
" $\alpha = 10°$,	$\theta' = 7° 14' 50''$, "	$\Phi = 29° 57' 00''$

From this table it appears that Φ is a maximum when α has some value not far from 20°.

If the point considered be P P′ for which $x = r \cos \tau = r \cos 39° 32' 23''$, and

$$y = b = r \sin 39° 32' 23'',$$

we have $\theta' = o$ and $p_1 = o_1$ $\therefore$ in equation (33) $\cos \Phi = \frac{a}{0}$, and from the same considerations as when $\alpha = 90°$, we find

$$\cos \Phi = 1, \text{ whence } \Phi = o,$$

without reference to what the value of α may be.

If, as is very probably the case, the direction of pressure is *not* exactly parallel to the P F, but inclines somewhat towards the plane of the right section of the soffit, the effect will be to *increase* the tendency to slide on the C j s's. Near the springing plane, however, the direction of pressure in a vertical plane will not be exactly parallel to the tangent to the oblique section, but will make a *less* angle with the H P, which will tend, especially when the obliquity is considerable, to counteract the previously mentioned effect. This refers to portions of the arch *below* P P′ for which $y = r \sin 39° 32' 23''$; *above* this, the tendency to sliding being in the *opposite direction;* if the line of pressure incline towards the plane of right section, it will decrease this tendency, and thus add to the stability of the arch. It is evident from inspection of the table of values of Φ that a *full centred* arch should not be built by this method unless with a small obliquity, and then it would need to be thoroughly supported by the spandrels.

These results differ entirely from those obtained in Chap. VII. of Buck's treatise on oblique arches already referred to; in fact, are in direct opposition to them. He derives a formula for the value of τ *dependent upon the obliquity of the arch*, so that τ decreases with α, or as the obliquity increases, and infers therefrom that the safety of the arch *increases* as it becomes more oblique up to about 25°. I should state that his τ has a slightly different signification from mine. He undertakes to find the point at which the curves Q P′c, Q P′d, etc., cut the intrados and extrados at the *same height* above the H P, and calls the angle included between a radius drawn to this point of the intrados and the H P the angle τ. It will be evident from inspection of the drawing that this would give to τ a somewhat *greater* value than I have obtained, but still *independent* of α, since the only constants in equation (9) are a_1 π, and r.

The following table taken from his book gives the values of τ obtained by Buck from his formula for certain values of α, from which he derives his inferences with reference to the security of oblique arches.

TABLE FROM BUCK'S ESSAY ON OBLIQUE BRIDGES.

When	$\alpha = 65°$,	then	$\tau = 27° 17'$
"	$\alpha = 55°$,	"	$\tau = 25° 13'$
"	$\alpha = 45°$,	"	$\tau = 21° 47'$
"	$\alpha = 35°$,	"	$\tau = 15° 38'$
"	$\alpha = 25° 40'$	"	$\tau = 0° 0'$

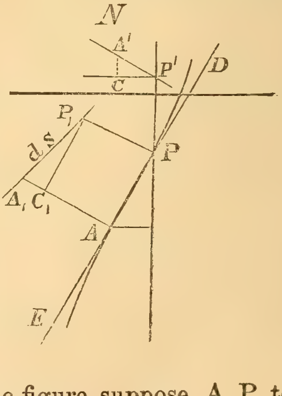
Immediately under this table he remarks, "It will be observed that the last angle is given 25° 40′, at which the point τ descends to the level of the axis of the cylinder, and *the whole semicircle is safe.*"* By looking at the table of values of Φ it will be seen that, for this value of α, Φ will be about 32° or 33° at 10° above the springing plane, τ of course being 39° 32′ 23″ instead of o, and hence the arch will be anything but safe if a complete semi-cylinder.

One incorrect assumption made by Buck in his derivation of the formula for the value of τ is as follows. He says: "It may be shown that the tangent of the angle which the tangent to the intradosal spiral makes with the horizon diminishes as cos τ." He does not show it, however.

Call the above mentioned angle ψ, and the angle between the tangent to the helix at any point and axis of the cylinder β, then the true relation is

$$\sin \psi = \sin \beta \cos \tau$$

$$\tan \psi = \frac{\sin \beta \cos \tau}{\sqrt{1 - \sin^2 \beta \cos^2 \tau}}.$$



In the figure suppose A P to be the horizontal projection of an element $d\ s$ of

*The *italics* are mine.

the helix coinciding with the tangent line D E. A′ P′ is its vertical projection, and $A_1 P_1$ its revolved position about a horizontal line in a vertical plane through P. The angle $A_1 P_1 C_1 = \psi$, and the angle $C A' P' = \tau$.

$\therefore$ $ds \sin\psi = A_1 C_1 = A' C = A' P' \cos\tau$;

but $A' P' = ds \sin\beta$;

$\therefore$ $\sin\psi = \sin\beta \cos\tau$.

At the springing plane the tangent to the elliptical section parallel to the P F becomes vertical, and the value of Φ is

$$(34)\quad \tan\Phi = \frac{h}{\pi r} = \frac{2}{\pi} \cot\alpha.$$

At the crown it is

$$(35)\quad \tan\Phi = \tan\theta' = \frac{(2-\pi)\cot\alpha}{2\cot^2\alpha + \pi}$$

The following is a table similar to table I, giving the values of Φ at the crown and springing plane, derived from equations (34) and (35).

TABLE II.

	At the Crown.	At the Springing Plane.
When $\alpha = 60°$	$-\Phi_c = 9° 50'$	$\Phi_{sp} = 18° 20'$
" $\alpha = 50°$	$-\Phi_c = 11° 53'$	$\Phi_{sp} = 28° 7'$
" $\alpha = 40°$	$-\Phi_c = 12° 49'$	$\Phi_{sp} = 37° 11$
" $\alpha = 30°$	$-\Phi_c = 9° 16'$	$\Phi_{sp} = 47° 48'$

$\Phi_c = \theta_c'$ is a maximum by equation (26) when $\alpha = 38° 35'$, for which value of α we find $\theta_c = 12° 50'$.

At the angle $\alpha = 25° 40'$—the last one given in the table extracted from Buck's work—the line which he finds to be horizontal makes an angle with the H P of a little more than 29° 51′, that being the angle between the tangent to the locus of equation (9) at the point R» C_2 and the H P.

It will be noticed that the negative sign of Φ_c in Table II. comes from the fact that in equation (35) π is greater than 2. It indicates that the tendency to sliding is in the *opposite direction* from what it is below τ.

THE STREET-PAVEMENT QUESTION.*

From the "Journal of the Society of Arts."

It would not be easy to find an illustration of the waywardness of public opinion, and of the inability, mental or moral, of the great mass of people, to award righteous judgment upon the various facts which are before them, clearer than appears in the controversy carried on as to the merits of wood and asphalte for pavements.

Interest and caprice struggle against manifest public utility, and it will be by accident, or by something more sordid, that the best will win. When these two forces contend, public good is too often used on either side as mere pretence.

1. It is submitted that impartial examination of the facts determines the conclusion that asphalte is the best known pavement. It has more of the qualities that are useful, and less of the undesirable, than any other substance.

2. Friction—resistance to moving bodies—is the unavoidable difficulty in the way of easy and rapid street transit. Asphalte causes the least friction. It is almost as smooth as the iron rail itself, and it is moreover elastic. Hence horse power is by it economized greatly. A heavier weight with equal power can be moved over asphalte than over wood or stone, except it be on steep gradients. Equal horse power will move a greater weight, hence asphalte is a better and kinder economy. A horse will draw his old usual load—almost always the utmost he can move—with less fatigue, thus that costly and interesting laborer, the horse, can live and work longer, and will therefore be rendered more profitable to his master.

3. The horse will have a more comfortable life of it by reason of asphalte. In these times, when such refined interest is lavished on the working classes of all sorts, the horse has some claim to be considered in public improvements, seeing that he is about the best behaved of his order, rarely requiring the policeman, and rarely deserving the whip, certainly not oftener than some other classes of workers. He joins not unions, nor strikes; in truth he submits but too quietly to some-

* From a Paper presented to the Society of Arts.

times very hard usage and hard fare. Greed unfortunately deprives him of the agreeable advantages of asphalte, and because he can now draw more than his former normal load, he is made to draw more. Some time ago, when it was proposed to raise and level Holborn valley, humanity urged claims on behalf of the horse; it was said he would not be urged to draw so heavy a load up-hill. An astute person said such is a mistake. "Level Holborn hill, and the horse will be the sufferer in the long run. Now, in his course from Aldgate to Oxford street he is loaded in reference to the difficulty of the hill, and therefore he is loaded under his strength for all the long remainder of his journey. Fill up Holborn hill, and more will be wrung out of him." This applies already to tramways, and will be applied generally to asphalte. The horse is no gainer, alas!

4. By reason also of its little friction, asphalte wears away and abrades moving bodies less, and thus it creates less dust. Its elasticity, though little heeded, helps this. Of its own proper substance the least possible is worn away. Some say it is not worn at all, but is forced out of perfect level and rolled closer, especially when there is continued pressure in one narrow line or groove. Hence it is not so well suited for narrow streets. Probably asphalte pulverizes less than any known body.

5. Asphalte is in itself clean, in itself or from its own abrasion, or it is clean compared with any other kind of pavement. It may be kept clean with the least labor and cost. All matters—and there are many—which are offensive to the senses and to the health, can be and are at once easily removed with even little or no stain. The cartway may be kept nearly as clean as the footway. Asphalte presents an even, smooth, and continuous surface. All other materials are joined, and the joinings are receptacles for the worst compounds of mud and dust. Hence the footway derives much of its dirt. Utmost cleanness is a prime condition of health and comfort. Dirt begins with the street, and ends inside the house, from the cellar to the attic, wherein are blown the unsavory matters of the street when in the state of dust. Asphalted clean streets are now especially required, seeing that disguised under fashionable costume, ladies—*i. e.*, those who do not ride in carriages—resolutely employ themselves in sweeping the dirtiest of the streets, whether of the mud or dust. The costliest and most delicate fabrics, gracefully or not gracefully attached to their persons, do the work of the besom or "squeegee." The proper course would be to let such matters flow away along kennels and sewers, but by a sort of antiperistaltic motion they are brought up into our homes, into our very kitchens and bedchambers. Moreover, what the domestic sweeps out of the house the fine lady brings back again upon her clothes and person; thus an ever revolving cycle removes and restores dust or mud poison. No sooner is the dirt of the house swept up and out, than it is brought back in no inconsiderable quantity.

6. We cannot annihilate mud and dust, but by the use of asphalte it can be reduced to its minimum, which indeed, is all that can be done in human affairs. To diminish evils is all that we can do. These are real practical gains, but understood only by observing persons. Few care about dust if it do not quite blind their eyes or make them sneeze. The poison of it they know not, nor do they care. Dust seriously injures the shopkeeper's costly stock, whether of fabrics or of watches or jewels. Whoever has looked at Cheapside and the Poultry in the granite age, looking from the Exchange westward, will have seen in clear dry summer weather an atmosphere of almost impalpable dust like fog. Under asphalte which has been down four years this is much less, indeed it is scarcely visible. Dirt is brought into our streets from distant places by carriages and by foot people quite unavoidably. Let us not through prejudice or interest infest the city with the maximum of this noisome evil, nor by block-pavement of wood, or stone, reticulate the streets with joints or meshes, wherein is collected dirt for redistribution again and again.

7. For the purposes of cleanliness asphalte bears the same relation to wood-blocks that modern crockery or china-ware bear to the ancient wood-trencher. Who would endure the wood-trencher of very doubtful cleanness—suspicious of sand—when he can have a smooth-glazed, absolutely clean plate of earthenware?

Or who would take his ale out of a wooden cup, or a gourd, if he could obtain a beaker of crystal glass, just because wood is less breakable? Better risk the breaking by slipperiness of these smooth cleanest surfaces of these plates or glasses.

8. This is clear, that carriages of all kinds last longer, much longer, when used on asphalte. The tyres, the spokes and naves, the springs and rivets, all that belong to chariot or waggon, are less shaken and not so soon worn up. Hence the money gain must be very considerable as to the greater durability of carriages which are moved over asphalte.

9. There are two evils which do pertain to asphalte to which wood-blocks are not so obnoxious. Horses do not get a sufficient foothold by which they can draw loads over gradients of 50° or 60°. For such places as London bridge and Ludgate hill, blocks of stone or wood must still be used. And why not? Who would insist on the constant use day by day of umbrellas and waterproofs against the contingency of a shower now and then, or of an occasional wet day? Who would keep a drag on the wheels of his carriage for the occasional incident of a steep gradient? The admitted evil of asphalte is its slipperiness in certain but very rare states of weather, such as do not occur once in 100 hours. Surely people honest and in their senses would not abandon the best known pavement because once in 100 hours horses are more liable to fall, and when they are fallen cannot so easily get up. When there is frost after thaw, streets are slippery by reason of ice. People just then must be more careful, and they must drive slowly, and use other appliances. Board-schools, among other things, will soon train up an intelligent race of drivers, or they will not be of much practical use. If people will drive fast without care, they must bear the consequences. Give drivers of public carriages some reward if their horses do not fall, and impose a small fine if they do fall, and an effectual remedy will be found.

10. Further, seeing how much ease and rapidity of transit is now enjoyed by reason of railways, which in the centre of the metropolis are almost continuous, it is not too much to require people, even our merchant princes, to allow ten minutes more in their crossing over the small middle passage, which is only now a few hundred yards from one railway to another. By metropolitan railways they gain time by the hour; let them submit to lose time by the minute for the greatest public improvement. So dangerous is rapid driving over certain central places, that it was once proposed that all carriages should proceed at a walking pace from the Exchange, the corner of Lombard street, Princes street, etc., just to the east end of the Poultry, where seven thronged streets converge. The objection made was fatal; it would interfere too much with the dearly cherished liberties of Englishmen, a liberty to be enjoyed in this case by riding Englishmen, of running down walking Englishmen. It is no refinement to say that by the use of asphalte the brain and head are relieved of the incessant rough vibration caused by transit over stones, and this relief must be beneficial to health. Who would willingly travel London streets paved with any other material but that which causes the least vibration, shake, or jar? This one advantage, fairly estimated, will probably quite weigh against the greater slipping for horses.

11. The remedy against this one evil of asphalte is complete. The contingency, which happens only during one hour in 100 hours, is to be overcome by the abundant use of sand or gravel, or by what is better—water. Water was tried in the city for fourteen days continuously, during a large portion of which long time it was not wanted; but so far as slipping was concerned, it was an effectual preventive. Can we overestimate the folly which rejects so admirable a pavement for a remediable evil, an evil which occurs so rarely?

12. The rival material is wood in blocks. Both are comparatively noiseless; wood is, indeed, more so. Asphalte returns the blow of the horse's foot, though not the noise of the wheel friction. The evils of wood seem to outweigh this one, or at most these two admitted advantages which it has—(*a*) wood is not slippery; (*b*) it is more suitable for gradients.

13. On the adverse side, wood is continuously wet or damp. Wood is porous; it is composed of bundles of fibres. It absorbs and returns wet—foul wet especially. The fibres of the wood are placed

vertically; the upper ends whereof fray out, are abraded, become like painters' brush stumps, and are about as permanently dirty; or they break up like the wooden handle of a chisel which has been struck with an iron hammer, or a wooden mallet when used upon an iron chisel. This fact is beyond all question. Wood is wet or damp more or less, except during continued very dry weather. Its structure is admirably adapted to receive and hold, and then to give off in evaporation very foul matters, which taint the atmosphere and so far injure health. The comparative condition of these rival pavements was well illustrated by King William street and the end of Cannon street, near the railway station, on Saturday afternoon, August 29. After a day of much rain, one was dry and clean, the other was intolerably muddy. Absolute cleanness and dryness is a prime condition; wood is the extreme contrary of this. It is absolutely dirty, and is almost continually damp. The joints of the wood are packed with tar, stones, and mud, and become magazines of poison whether they remain dry or not. Asphalte presents a continuous smooth surface, impervious to wet, while wood pavement, made of reticulated meshes or net-work, collects and holds dirt and damp poison intermixed.

14. There is another evil to which wood pavement is liable, and it should be no further used until more proof is obtained one way or another by the experiment of a severe winter. It is suggested that an accumulation of water will form a substratum, and then by the expansion caused by frost, will dislocate the blocks, and by their uprising will render the surface very uneven, will loosen the blocks themselves, and cause them to eject water from the interstices when the thaw comes. The accumulation of water and its subsequent ejection between the wood interstices is shown already by the present condition of King William street, especially near the statue. We need not wait for the distinct force of frost, for to-day (September 7) there are considerable pools of water (foul water) in various places, which evidently come from below. Here is all the mud of the olden time brought back again. The asphalte close by is quite clean and dry. It is usually dry an hour or two after rain. Moreover, the wood-blocks themselves are already very much worn; the interspaces have become wider and very ragged. Wood will not endure the severe action of waggon-wheels, breaking sharp flint pebbles into saws, knives, and rough wedges. These are fast destroying the wood-pavement. Not another yard of wood should be laid down anywhere until the coming winter has passed; *i. e.*, until April 1, by which time the wood-pavement of King William street will probably be worn into rags, like old felt roofing. If such be its present ragged condition at the end of a most favorable summer, we ought to continue the experiment during the severe trial of the coming winter before extending its use. There is no need of so much hurry, except in the interest of trading parties, who would of course rather get the streets paved with wood before its evils are better known. Mr. Heywood's report, 17th March, 1874, is admirable for logical precision. It sets forth with judicial impartiality the relative good and evil of wood and asphalte. The public is left to judge. While Mr. Heywood seems no partisan, there can be no doubt that his paper leaves the fact established that asphalte is the best pavement known. In concluding these remarks, I beg to observe that I have no interest whatever in the question, other than having an anxious wish that the comparative merits and demerits of the two materials—wood and asphalte—should be candidly examined and proved by observation and experiment.

N. B.—To meet the difficulty respecting gradients it has been ingeniously suggested that broad tramways should be laid for the wheels, and a paved or macadam footway be preserved in the middle of the streets for the horses' foothold.

Iron gives a description of a monument recently erected by the town of Boulogne-sur-Mer to Fréderic Sauvage, who in France is considered to have the largest share of merit in practically applying steam to the screw as a motive power. Sauvage spent his days and fortune in perfecting inventions which brought him no profit; passing finally from a debtors' prison to the madhouse, where he died July 19, 1857.

SAFETY VALVES.

From "The Engineer."

The Institution of Engineers and Shipbuilders in Scotland deserve great credit for the energetic attempt they have made to settle the vexed questions connected with the construction of marine safety valves, with which our readers can hardly have failed to render themselves familiar. The action of the Board of Trade has long been felt to be oppressive in several matters connected with the construction of marine engines and boilers; and the code of rules laid down by the Board for proportioning and weighting safety valves has been pronounced especially objectionable. For a long period only dead-weighted valves would be passed by the surveyors of the Board; and although this rule has been somewhat relaxed, all valves not loaded with dead weights are still looked upon with doubt and suspicion. The rule that marine safety valves must invariably have a minimum area of half a square inch for every square foot of fire-grate is, however, still rigidly enforced; and this without any regard being had for the peculiarities of the valve, the rate of combustion, or the pressure at which the valve is intended to blow off. If it could have been shown that the area fixed by the Board of Trade was the best that could be adopted, no one would have had reason to complain; but engineers familiar with the subject have long felt that the rule has no solid basis of experimental fact; that it was adopted, in short, simply because the Board of Trade do not know of any better rule, and are too indolent or too careless to endeavor to frame a rule which would be more satisfactory. The Institution of Engineers in Scotland includes among its members a very large number of marine engineers, and questions connected with safety valves have, as a matter of course, been freely and frequently discussed by those gentlemen at the ordinary meetings of the institution. The subject was of vital importance indeed to them, and as little progress could be made with the Board of Trade, it was at last determined that a committee should be appointed to investigate the action of safety valves experimentally, and report on the whole subject to the institution. The committee assembled consisted of Messrs. Walter Brock, James Brownlee, J. L. K. Jamieson, E. Kemp, H. R. Robson, and David Rowan. The report prepared by these gentlemen was laid before the institution about four weeks ago. It has since been printed and issued to the members, and a copy now lies before us. It is a sufficiently interesting paper, and will add to the reputation not only of the institution, but of the three engineers, Messrs. Brownlee, Rowan, and Brock, by whom it has been mainly prepared. The first-mentioned gentleman contributes an able investigation of the laws determining the outflow of steam through orifices; the second, the results of experiments made by him to ascertain the pressure to which steam will rise in a boiler above the load pressure, with valves having half a square inch of surface per foot of grate at different pressures; while Mr. W. Brock supplies the results of experiments which he has made regarding the strength and action of springs as applied to the loading of safety valves. All the experiments were practically new, and were carried out with special apparatus and great care. The report as a whole is so lengthy that we cannot find space to reproduce it entire. Extracts will however be found on another page, and we shall explain here some of its more important results and deductions.

An investigation of the laws of the outflow of steam was obviously required as a basis for any reasoning on the propriety of the Board of Trade rule. It is true that many experiments have already been made to this end by Napier and others, which have shown that Weisbach's theory was erroneous; but the committee wisely determined not to rest content with what had been done by others, and so they constructed special apparatus, which we illustrate in another place, and reinvestigated the subject, with results in the main confirming the views of the late Professor Rankine, as enunciated in "The Engineer" in November and December, 1869. One of the most important conclusions at which the committee arrived is that the Board of Trade rule, specially intended, be it observed, to apply to the case of boilers working with moderate pressures, is for those pressures radically wrong, while it is only approximately correct for higher pressures such as are carried in the present day. As an illustration of the truth of our assertion, we may cite an example given by the committee. An experimental boiler was fitted up. This boiler had two furnaces, 25 square feet of grate, and 746 square feet of heating surface. It was provided with two safety valves, each 2⅞ in. diameter, or 6.49 in. area. The total area was thus practically 12.5 in., or half a square inch per foot of grate, and therefore in accordance with the Board of Trade rule. The valves were loaded with dead weights, and were in all respects in conformity with the received regulations. Now the special object of the Board of Trade engineer surveyors in determining the area of safety valves, was to prevent any considerable augmentation of pressure after the valves began to blow. If the regulations do not insure this, they must be regarded as imperfect, if not utterly useless. Now what are the facts? With a load of 5 lbs. on the square inch, these approved valves absolutely allowed the pressure to rise to 13 lbs., or to 160 per cent. more than they ought! It may be urged that this pressure is lower than would be met with in practice, and that the matter is therefore so far of little consequence. But this cannot be said of a pressure of 25 lbs. on the square inch. When loaded to this, the valves permitted the pressure to accumulate to 36 lbs., or, in other words, to 44 per cent. more than they ought; and even with 45 lbs. the pressure accumulated to 52 lbs., being an augmentation of 15.5 per cent. In all cases the lift diminished—as we have often pointed out that it does—as the pressure increased, being for 5 lbs. .325 in.; for 25 lbs., .1425 in.; and for 45 lbs., .097 in. It will thus be seen that the Board of Trade rule really supplies no safeguard whatever, and that boilers fitted with valves passed by the surveyors may be in hourly danger of explosion. We have heard it argued that sea-going engineers cannot be trusted to ease a valve or reduce the formation of steam, and that for this reason care must be taken to supply them with safety valves which will be certain to relieve the boilers no matter how careless or incompetent the engineer in charge may be. With the preceding facts before us, it will be seen that very serious accidents must have occurred over and over again if engineers had not used that common sense with which the Board of Trade refuse to credit them. To show still further how imperfect and insufficient the "half-inch rule" is, we may state that the committee give a table of the proper areas of valves for various pressures from 20 lbs. to 75 lbs. For the first, the required area of valve in the case of a boiler with 25 square feet of grate is 45 square inches, equivalent to two valves each 5⅜ in. diameter; while at 75 lbs. an area of 12 square inches would suffice, or a little less than that enforced by the half-inch rule. This table is inconclusive, because the committee do not supply any information as to the actual experiments on safety valves from which it was deduced; and it remains to be proved that any safety valve of the ordinary construction, no matter what its area may be, and loaded as the Board of Trade dictate, could prevent a very considerable augmentation of pressure.

As regards the loading of safety valves by springs, we reproduce Mr. Brock's paper, so that we need not further refer to this portion of the report just now. The final conclusions arrived at by the committee we give here in their own words:

"(1) The present practice in this country of constructing safety valves of uniform size for all pressures is incorrect. (2) The valves should be flat-faced, and the breadth of face need not exceed one-twelfth of an inch. (3) The present system of loading valves on marine boilers by direct weight is faulty, and ill adapted for sea-going vessels, a considerable quantity of steam being lost during heavy weather, in consequence of the reduced effect of direct load—the result of the angle or list of the vessel, and also of the inertia of the weight itself, the latter not being self-accommodating at once to the downward movements of the vessel, and, moreover, the impossibility of keeping the valves when so loaded in good working order. (4) That two safety valves be fitted to each marine boiler, one of which should be an easing valve. (5) The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:

$$A = \frac{18 \times G}{P} \text{ or } A = \frac{0.6 \times HS}{P}$$

A = area of valve in square inches.
G = grate surface in square feet.
HS = heating surface in square feet.
P = absolute pressure in lbs. per sq. in.

(6) The committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing valve. The other may be so constructed as to lift one-quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers:

$$A = \frac{4 \times G}{P} + \text{area of guides of valve,}$$

$$\text{or } A = \frac{.133 \times HS}{P} + \text{area of guides of valve.}$$

This valve should be loaded say 1 lb. per square inch less than the easing valve. (7) As experience in the use of valves of this description is acquired, both may be of this kind, and one of them made to blow into the sea without any increase of pressure, the other to be the easing valve, and loaded 1 lb. per square inch in excess of the working valve. (8) If the heating surface exceeds 30 ft. per foot of grate surface, the size of safety valve is to be determined by the heating surface. (9) As boilers decay from age, it is necessary gradually to reduce the pressure of steam, and the committee recommend that valves should be made of a size to suit the pressure to which the boiler may ultimately be worked when it becomes old. (10) Springs should be adopted for loading safety valves, and they should be direct-acting where practicable. When levers are used, the friction of the joints will cause an extra resistance, and consequent increase of pressure, when the valve is rising, and a loss of steam through diminution of pressure before it will close."

We believe our readers will side with us in regarding these conclusions as temperate; but we are by no means certain that the formulæ given above will be universally accepted as satisfactory. That the report is opposed to the conclusions of the Board of Trade is not the fault of the committee. We have no desire to speak harshly of the action of the Board of Trade as regards safety valves; on the contrary, we believe that the engineers who prepared the objectionable rules did so conscientiously, and in the belief that they would secure the maximum amount of safety. Our complaint is that the officials of a great department have not willingly gone with engineers, and modified their regulations in deference to the wishes of the great body of marine engine builders in this country. If they make rules, they should be prepared to substantiate them, and to prove that they are satisfactory in every respect, and that their sufficiency and completeness is a full equivalent for their arbitrary characteristics. But the Board of Trade have done nothing of the kind. The rules they have prepared are not only empirical, but opposed to well-known laws. It must not be supposed, for example, that it has now been proved for the first time that as the pressure increases the area of a valve may be diminished. That fact has, in its broad sense, long been known. The Institution of Engineers in Scotland have, however, been the first to prove the fact on a sufficiently large and practical scale. If it could be shown that the half-inch rule erred on the right side, and gave too large a valve if anything, then there would be a legitimate excuse for its enforcement; but it actually errs, and that considerably, on the wrong side. Thus, there are many old steamers running now, and carrying passengers daily, the safety valves of which are loaded to but 15 lbs., and in some cases to but 10 lbs. on the inch, these being reduced pressures adopted because the boilers are more or less worn out. Although the furnace plates may be weak and the uptakes patched and honeycombed, the steam-generating powers of such a boiler are not impaired if it has been kept fairly well scaled. A considerable rise of pressure in such weak boilers is a very serious matter indeed. But it is none the less a fact that if such boilers have dead-weight safety valves, and half an inch of area per foot of grate surface, they will be passed by the Board of Trade surveyors—if otherwise all right—as safe; and this in the face of the fact that the pressure may, under these conditions, rise from 10 lbs. to 19 lbs., or 90 per cent., or from 15 lbs. to 25 lbs., or 66 per cent., or possibly to greater pressures than the makers or the Board of Trade ever intended the boilers to carry when quite new.

ETCHING IRON.

From "Iron."

Much time and attention has been devoted by Prof. Kick, of Prague, to the subject of etching iron with acids. His method is not a new one for arriving at a knowledge of the quality of iron or steel, having been used with some success for a long time, but the care with which the professor has conducted his experiments makes them exceedingly valuable.

Some kinds of iron exhibit what is known as the passive state, and are unacted upon by acids until this state has been destroyed by heating. The surfaces thus prepared were inclined to rust very soon. After a series of experiments with nitric, sulphuric, and hydrochloric acids, and etching solutions of copper salts, Prof. Kick found that a mixture of equal parts of hydrochloric acid and water, to which was added a trace of chloride of antimony, was the best etching solution. The chloride of antimony seems to render the iron less inclined to rust, so that, after washing thoroughly in warm water, and applying a coat of Damar varnish, the etched surface may be preserved quite clean.

The smooth surface that is to be etched is surrounded with a ridge of wax an inch high, as is done in etching copper plates, and the acid is poured into the disc thus formed. At a temperature of 55 to 65 deg. Fahr. the action soon begins, as shown by the gas evolved; in winter, the etching is poor. The time required is from one to two hours, but the etching should go on until the texture is visible. Every half hour the acid can be poured off without removing the wax, the carbon rinsed off, and the surface examined. If too much chloride of antimony is added to the acid, a black precipitate will soon form, which can easily be distinguished from the carbon. One drop of chloride of antimony to the quart of acid is sufficient. When the etching is finished, the wax rim is removed, the iron washed first in water containing a little alkali, then in clean water, brushed, dried, and varnished. If in a few hours it begins to rust, the varnish should be removed with turpentine, which will also take off the rust, and then varnish again.

The appearance of different kinds of iron when etched is essentially as follows: Soft or sinewy wrought iron of excellent quality is attacked so equally by the acid, and so little carbon is separated, even after several hours' action, that the surface remains bright and smooth. Fine grained iron acts the same; the surface is still smoother, but a little darker. Coarse grained and cold-short iron is attacked much more violently by acid than the above. In ten minutes, especially with the latter, the surface is black. After thirty minutes a black slime can be washed off, and the surface will remain black in spite of repeated washings, and exhibits numerous little holes. Certain parts of the iron are usually eaten deeper, while others, although black and porous, offer more resistance. By allowing the acid to act for an hour or so, then washing, drying, and polishing with a file, a distinct picture is obtained. Malleable cast iron, we know, rusts more easily than wrought iron, and it is interesting to know that the action of acids is also violent, the surface being attacked very violently. Grey pig-iron acts like steel; the etched surfaces have quite a uniform grey color. In puddled steel the color, after etching and washing, is grey, with quite a uniform shade, and the lines are scarcely visible. Cement steel has a very similar appearance, the lines being very weak. In Bessemer and cast steel the etched surfaces are of a perfectly uniform grey color, with few if any uneven places. The softer the steel the lighter the color.

On etching, the finest hair-like fractures are rendered prominent. A piece of steel, which looked perfect before etching, afterwards exhibited a hair-like fracture throughout its whole length. When different kinds of iron are mixed the acid attacks that for which it has the greater affinity, while the other is less acted upon than if it were alone. Etching is exceedingly valuable to all who deal largely in iron, as it enables them to determine with comparative accuracy the method of preparing the iron, as in the case of rails, &c., as well as the kinds employed.

ENGINEERING PROGRESS.*

From "Engineering."

It is a widely admitted fact, that the enormous impulse given to all industrial pursuits during the present century has been in a large measure due to the subdivision of work and specialization of effort.

A law of development is now recognized by some of the deepest thinkers of the present age, as controlling all growth and progress. The principal feature of this law is the subdivision of work. The development of an animal from a lower to a higher form of life is attributed to the different functions of the body gradually becoming more individual and special in their action. It is suggested that in the lower forms the different functions of respiration, digestion, circulation, etc., are performed by parts which appear to be very slightly different and hardly divided from one another; that, as you progressively examine the ascending forms of life, their differences and divisions become more and more definitely marked, each function being gradually allotted to special parts, which act to the mutual advantage of each other, the digestive organs performing their functions not only for the benefit of themselves, but also for the benefit of the lungs, the heart, the brain, etc., all of which are mutually dependent upon each other, any want of harmony in the action of one being at once felt by the animal which forms the aggregate of all these functions. The higher the organism the greater the organization, such as I have described, until we arrive at man, the greatest and most perfect of God's creatures, whose wondrous functions of body and mind are elaborated, divided, and specialized to an extent far beyond what we see in any of the lower forms of life. Similarly in social life, which is the aggregate of individual life, the most savage tribes are those which do not possess any subdivision of labor, and the highest state of society is that in which the subdivision of labor is carried to the greatest extent.

From these modern theories it would appear that progress in civilization, or growth of any kind, must depend upon the division of labor or specialization of function.

The progress of an art is also subject to the same law; the more you subdivide the processes the simpler each step appears; and the energies of a much greater number of men can be brought to bear upon the various subdivisions. Hence the gigantic development in our arts during this centnry.

What has been stated generally with regard to the arts is especially true in the case of engineering. Engineering may be described as the art of applying, controlling, and modifying the various forces of nature resident in matter to the mechanical advantage of man.

The early engineers were men who, with large grasp of mind, and proportionate energy, attacked certain problems, and with limited resources succeeded in overcoming the natural difficulties of their enterprises, in such a way as to encourage their successors, with more extensive resources, to still greater efforts. As the number of the profession increased, the great variety of the problems presented to their consideration naturally led to the subdivision of work, and we now find numerous branches of engineering, each branch having its own special followers. By this arrangement, the work in each branch is better done, because each individual brings his mind to bear on a limited range of subjects, leaving other specialties to the efforts of other men. For the benefit of the whole community this subdivision is undoubtedly a great advantage, and every engineer who makes a fresh subdivision of employment confers a boon upon society, and helps forward the development of engineering as an art.

But it must not be hidden from observation that this specializing of effort has, unless closely watched, a narrowing effect upon the individual, due to the small sphere of work in which his intellect is exercised, sacrificing those nobler and wider inquiries of the human mind, which a more extended field of occupation offers.

* Inaugural Address delivered to the Members of the Cleveland Institution of Engineers by the President, Mr. Thomas Wrightson, A. I. C. E., M. I., M. E.

It does not require a very close scrutiny into the engineering works of the present day to verify the fact, that the bulk of such a work is a repetition of previous work which has proved successful, the principal originality being when the engineer has to adapt previous experience to altered conditions. Thus the civil engineer has to take into account variations in climate, geological formation, contour of country, rainfall, and many other conditions, before he can select which of the oft-tried plans of executing any particular work it is expedient to use. The mechanical engineer has a fund of devices from which, according to the exigencies of the case, he may select a particular method of accomplishing his work. So also the mining engineer. From this it might appear that modern engineering does not tend, in the present condition of knowledge, to increase greatly in originality.

Again, commercial success being the great requirement of the ordinary capitalist, originality is to him a secondary consideration, so that he is tempted to discourage the endeavor to introduce anything which has not previously been proved successful.

These considerations make us fear that the future of engineering may be one of less nobility than we have been accustomed to hope for, after reading the achievements of Smeaton, Watt, the Stephensons, Brunel, and others, who originated the methods now so freely resorted to in ordinary practice.

It behooves us, then, to inquire whence the future impetus to the progress of engineering science is likely to be given. According to our definition, we as engineers have to do with the various forces of nature. These forces become perceptible to us through the medium of matter. It is therefore highly necessary that we fully understand the nature of matter and those conditions of matter which we call force.

Sir Isaac Newton immortalized himself by discovering the laws which govern the motion of masses of matter. By his demonstration of the laws of gravitation, a great impulse was given to physical inquiry, an impulse which has been maintained ever since his time, and which has led to marvellous results. The laws of the science of chemistry, as first laid down by the celebrated Dalton, opened a fresh field for physical inquiry, the nature of matter in its atomic condition being attacked. Then came the gradual acceptance of the undulatory theory of molecular motion, which, through the labors of Dr. Young, Chladni, Savart, and others, was accepted as accounting for the phenomena of sound as propagated in air, and then led to the acceptance of the same wave theory as accounting for the propagation of light, heat, and electricity, through the more subtle ethereal medium in which they travel. From the nature of such investigations the progress of the science of molecular physics has been slow, but the physicists of the last 30 years have made rapid strides, and by careful experiments and rigid reasoning, have been able to demonstrate conditions of matter and force which, although unperceived by the senses of sight, hearing, touch, or taste, can yet be visualized in the mind by the seeker after physical truth.

In the study of matter, and the forces to which it is subject, the unity of creation has been impressed upon the student, and every year seems to bring fresh proof of the co-relation of all the known forces of nature. Let us then consider in what way the engineer has been or may be benefited by the study of the molecular forces.

The phenomenon of electricity was, not many years ago, looked upon as an amusing experimental curiosity. Scientific men investigated the subject, studied and classified the various phenomena, until in the fulness of time arose Wheatstone, who utilized this plaything, converting the curious toy into the most wonderful means of communication ever given to the civilized world. Wheatstone, by this application of science, gave to engineering a new department. Telegraphic engineering is now a specialty, which, like all other branches of the art, demands a knowledge of other sciences, many of which had hitherto been considered as quite remote, and dissociated from electric science. Without a knowledge of physical geography, the telegraphic engineer could not undertake the laying down of a submarine cable. He must know much respecting the currents of the ocean, of its depths and temperature. He has to design machinery, and invent processes for the proper manufacture and testing of the coils. He has to adapt and design vessels for their transport, with necessary machinery for their safe and effectual laying. This is now an enormous industry for which we have to thank the physicist. Practical success always stimulates further inquiry, and we may be sure that electric science, as studied by such men as Sir William Thomson, Mr. C. W. Siemens, and others, will yield still further results for the benefit of mankind.

Let us now consider the connection which exists between the physical science of chemistry and engineering. If we begin at home, we cannot but see that the mysteries of the blast furnace can only be solved by the aid of chemical science. With the exception of a small number, the ironmasters and blast furnace engineers of this and other districts do not scientifically study the working of their furnaces. Great difference of opinion exists as to the effect of certain conditions, the result of which is, that there are, perhaps, not two "plants" in Cleveland in which the conditions of the construction and the working of the furnaces are the same. Every one seems to have imbibed some peculiar notion, which he supports with a confidence frequently inversely proportionate to his information. A advocates great height and small bosh; B large bosh and moderate height; C pledges himself to a flat bosh; D to a steep one; E considers nothing affects more favorably than a large bell; F will have nothing but a small one; G thinks that an open top gives a better quality than a close one; H quite differs from him; I stakes his reputation on high heats; J condemns them; and K out of another district says the blast should not be heated at all. And we might go through several alphabets to illustrate the number of points upon which in blast furnace practice variety of opinion exists.

As in the search for all physical truth, there are two paths by which we must come to a knowledge of the principles involved in the working of a blast furnace. From the known laws of chemistry much that takes place in the furnace can be deduced; but there is also much that in our present state of knowledge is beyond such inference. To remedy this want of knowledge, reliable and well-authenticated facts are required. These facts, if collected on a scientific plan, not from the plant of a single ironmaster, but from every furnace plant in the district, would, under the searching scrutiny of scientific men, soon lead to the clear perception of laws which are as yet imperfectly understood, though occasionally stumbled against by enterprising gropers after truth. Of one fact we may be sure; that there are laws governing the action of a furnace which cannot be contrary to the truths of physics, and it is only by the aid of the known laws of physics that we can intelligently compare the evidence of facts respecting the working of furnaces, which by an organized scheme of observation may, we venture to hope, some day be collected in this growing district.

Again, as another example, take the important connection between molecular physics and the strength of materials. It seems almost a law of nature that the transmission of any force through the medium of matter involves the change of a portion of that force. As in the transmission of the power of steam through the steam engine a portion is lost as mechanical power, and appears as frictional heat, so in transmitting power through a shaft or chain, a portion of that power appears to go towards producing a molecular change in the atoms of the iron, which, in the course of time, permanently affects the useful qualities of the material. These changes are probably of a chemical and a mechanical nature. How little is really understood by the engineer about this important element in the strength of material, and how many lurking dangers menace the public in consequence! Take for example the phenomenon of seam-rips in the egg-ended boilers so much used in this district. From some tests I have lately been making of the iron cut from the plates of two different boilers which had ripped at the seam, I found that the flame playing at the convex bottom of the boiler had affected the iron at the seam so as to make it cold-short, of small tensile power, and apparently crystalline in its fracture. Further from the seam the iron appeared in all cases less injuriously affected. On annealing pieces of the iron cut from the seams, it was found that the cold-shortness had disappeared, and that the tests both for tensile power and ductility had been restored to their original condition. The plates in one of these boilers were Staffordshire, and in the other the best make of Cleveland boiler plate. In the former the seam-rip experimented upon had led to an explosion which resulted in the destruction of much property, though happily of no lives. When we consider the hundreds of seam-rips which occur, but are detected in time to avoid explosions, we appreciate the importance of understanding fully, by the study of chemistry and physics, the molecular changes which occur in a boiler plate by the action of fire; as, if this action cannot be neutralized by some process of manufacture, it is important for the engineer to scheme some form of boiler which will be least likely to invite the attack of this insidious enemy.

Let us now glance at another most important investigation of the physicist which has hitherto been unknown to many calling themselves engineers, but which holds out the promise of being the means of making us acquainted with many new facts, as well as of explaining many old ones. I allude to the theory of the conservation of energy. The leading idea of this theory, as worked out by Carnot, Mayer, Helmholtz, Clausius, Joule, Rankine, Sir William Thompson, and a few others, is, that in the universe there is a definite quantity of force of all kinds. These forces are heat, electricity, mechanical and chemical energy, magnetism, etc.; and each of these forces is capable of being converted into any other of them, but the total quantity of force in the universe remains the same. Thus, heat may be converted into mechanical energy, as by the expansion of a heated rod of iron which can be utilized in several ways to do work; or by the production of steam, which works a steam engine, thus producing mechanical work. Chemical energy can also be converted into heat and mechanical work, as when a charge of gunpowder propels a bullet, part of its force going towards the heating of the gun and projectile, and part to the propulsion of the ball. Electricity can also be converted into heat, mechanical power, or chemical energy. Whatever changes take place in the form of energy, the total amount in the universe, by this theory, does not diminish or increase. It may be lost to this world, as by radiation of heat into space the earth becomes cooler; but, as energy, it is still in existence in the universe.

Now this generalization has not been arrived at without minute experimental investigation. Mr. Joule, an eminent physicist of Manchester, twenty-five years ago, made a series of careful experiments to ascertain the relation existing between a given amount of mechanical force and the heat generated by it. The experiments were conducted in the following manner: A certain weight was made to descend a certain number of feet, and in doing so, by means of a silk thread passing over pulleys, to turn a small vertical shaft in a vessel full of water, oil, or mercury. Paddles were fixed to the vertical shaft, so that the power exerted by the weight (with the exception of a measurable proportion lost in friction of pulleys, etc.), went to the production of heat in the liquid through the agitation of the paddles. After numerous experiments, Mr. Joule arrived at the following valuable scientific fact: that a weight of 1 lb. descending through 772 ft., or a weight of 772 lbs. descending through 1 ft., develops mechanical energy which, when converted entirely into heat, will raise the temperature of 1 lb. of water 1 deg. Fahr. This is called Joule's equivalent, and is concisely expressed by Rankine, in his definition of the first law of thermodynamics, as follows: "Heat and mechanical energy are mutually convertible, and heat requires for its production, and produces by its disappearance, mechanical energy in the proportion of 772 foot-pounds for each British thermal unit"—the said thermal unit being the amount of heat required to raise the temperature of 1 lb. of liquid water 1 deg. Fahr., at or near the temperature of the maximum density of water, viz., 39.1 deg. Fahr.

It must be clearly understood that mechanical energy can only be entirely converted into heat when no mechanical work is transmitted. For instance, if, while Mr. Joule's paddles revolved, a portion of the liquid had been raised permanently to a higher level, the heat generated in the liquid would then have been so much less in proportion to the mechanical power so transmitted: or if the whole of the water could be raised such a height as to reproduce the whole of the energy of the descending weight, there would be no increase of heat in the liquid. For every foot-pound of mechanical energy which is lost, a definite quantity of heat is generated, and when work is performed by the consumption of heat, for each foot-pound of work gained an equivalent of heat disappears. Professor Tyndall performs a beautiful experiment, illustrative of the loss of heat when work is performed. He takes a rigid hollow vessel, and pumps air into it until of a considerable pressure. After allowing it to cool down to the temperature of the room, he places a delicate thermopile (which will show the slightest variation in temperature) in front of a stop-cock on the vessel. On opening the cock the air rushes out of the orifice against the face of the thermopile, which indicates at once a *fall* of temperature. He then takes a pair of bellows, and through a nozzle the same size as in the previous experiment, he presses air by the action of his muscles against the face of the thermopile. This time the pile indicates a *rise* of temperature. Now, why this difference?

The old material theory of heat could not have accounted for it, but the dynamical theory of heat makes the reason obvious. In the case of the rigid vessel, the air itself, by its elasticity, performs work in forcing its way through the aperture at a high velocity. Work exerted means loss of heat, whereas in the case of the bellows the work is not done by the air, but by the arm of the operator, and it is from his muscle that the heat disappears, only to be restored by the fuel, which, in the form of food, it is necessary for him to consume. The heat produced in the case of the bellows is due to the striking of the issuing air against the face of the pile. The same cause produces heat in the case of the first experiment, but the consumption of heat more than counterbalances this. From this experiment, and the reasoning therefrom given us by the physicist, we as engineers can carry the application still further into our practice: we can see now why we are not scalded when we put our hand in a jet of high-pressure steam issuing from a small orifice: also why the hot blast which escapes at the pricking hole of a blast furnace is so much reduced in temperature. We can comprehend the fact that the temperature at the tuyere may be perceptibly less than that in the stove, according to the mechanical energy exerted by the reservoir of air to force the front particles forward. We can also detect the loss of heat and consequent power which results from wire-drawing of steam, and can appreciate the advantage of having direct and large passages for the steam to pass to the engine. The effect of the use of Gifford's Injector upon the temperature of a boiler, and many other phenomena which will suggest themselves to the thoughtful engineer, will be found to bear close relation to this wonderful law of the conservation of force. The problem of the engine builder is to convert heat into mechanical power. He is wonderfully assisted by Nature in this work. In the first place she has laid up a large store of unconsumed carbon, in the shape of coal, which is eminently suitable for the production of heat. She has further provided a boundless store of oxygen in the atmosphere, in a chemically uncombined state, and therefore available for combination with the coal to produce this heat. She has also ordained that the commonest substance on this earth, viz., water, should be the most convenient for using as a medium in converting heat into mechanical force, on account of the low temperature at which it is converted into elastic vapor.

We shall not have time at present to do more than consider whether the study of molecular physics is likely to throw any light upon the important question of raising steam.

The heat produced by combustion is simply the chemical combination of the oxygen of the air with the carbon of the coal. The atoms of the two gases, according to modern theory, rush into chemical combination, and the clashing of these atoms together produces the phenomenon of heat. This heat is not, as was formerly supposed, a substance dwelling in the interstices of matter, but is, as described by Helmholtz, a peculiar shivering motion of the ultimate particles of the heated substance. This atomic motion is transmitted from the heated gas to the plates of the boiler, the atoms of which take up the shivering motion and transmit it to the water inside.

At a conveniently low temperature this

motion of the atoms of water has increased to such an extent that they shake themselves beyond their cohesive force and fly asunder, forming steam.

Now it has been proved by chemical experiment that a pound of the purest coal gives out, when entirely burnt, sufficient heat to raise the temperature of 15,664 lbs. 1 deg. Fahr. The aim of the engineer should be to obtain as large a portion of this heating power as possible; but, with the best results of the most economical boilers, only about 59 per cent. of this power is obtained.

I have taken this proportion from the results of some very exhaustive experiments which have been lately made by M. Lhoest in Belgium, upon the boilers of a 110 horse-power compound steam engine. These are fully reported in the English edition of the *Universal Review of Mining*, for March, 1874, and are well worthy of study. M. Lhoest shows, by a series of observations, that the total effective heat transmitted to the steam was only 59.59 per cent. of the theoretical heating power of the coal as calculated from its components parts. I may say that the above result was from generators somewhat resembling that kind known in England as the elephant boiler, the heating surface being very large, and the steam superheated. The heat of combustion was utilized to such an extent that the temperature of the escaping gases on their entrance into the chimney was only about 350 deg. Fahr. This result was therefore exceptionally favorable, as we may see by referring to Mr. Jeremiah Head's paper on the efficiency of steam engines and boilers, read in 1869 before the members of this Institution, where he shows that we only utilize in this district, in ordinary good practice, 47 per cent. of what is chemically possible. M. Lhoest, from chemical reasoning founded on direct experiment, estimates the remaining 40.4 per cent. of loss to be made up as follows:

	Per cent.
1. Combustible matter lost in the cinders (Charleroi coal used of poor quality)	9.1
2. Gases escaping through chimney	5.43
3. Imperfect combustion	5.07
4. Evaporation of $1\frac{1}{2}$ per cent. of water in fuel	.12
Radiation, or losses through the brickwork, losses arising from the cleaning of grates and other causes not estimated	20.52

It must occur to any close observer that the 20.5 per cent. is a very unsatisfactory item, and that as engineers we ought to endeavor to reduce this amount to a minimum. Apart from the loss by radiation through brickwork, let us consider whether there may not be a loss in the transmission of heat from the gas through the medium of the plate to the water. We are all familiar with the Davy lamp, the principle of which is, that a flame is cut off by the intervention of wire gauze of a suitable mesh. If you take a sheet of fine wire gauze and hold it over a gas jet, you will find the space above the point where the gauze cuts the flame to be quite dark, although the gas is streaming through the meshes; and if you blow out the gas jet, holding the gauze in the same position, you can absolutely light the flame above the gauze, while between the gauze and the nozzle of the gas pipe there is no flame to be seen. Professor Tyndall, in his valuable work "Heat a Mode of Motion," explains this phenomenon as follows: "The molecular motion of the flame is very intense, but its weight is extremely small, and if communicated to a heavy body, the intensity of the motion must fall, as when a two-ounce rifle bullet strikes a 100-pound shot, the motion of the heavy shot is small compared with that of the light bullet."

The intensity of the motion of the flame, being taken up by the molecules of the heavy gauze, is so much lowered that it is insufficient to transmit the necessary heat to produce ignition on the other side of the gauze.

Now, is not this action somewhat analogous to the transmission of heat through a boiler plate? Is there not a loss of heat in passing through the plate? Is not a portion of this molecular motion, in changing its velocity, changed into some other force? I have already alluded to certain molecular changes, which are proved, by testing, to have taken place in the case of the two boilers in Cleveland which ripped at the seams. Here is no doubt the evidence of a change of a portion of heat into another form of energy. This view of the destruction of heat by transmission through the plate of a boiler is probably favored by the result of experiments made on Warsop's system of pumping heated air into a boiler, to assist the generation of steam. It has been declared by competent authority that there is a positive gain in this process, notwithstanding the mechanical loss which the pumping of the air involves. May not the explanation of this be, that the conveyance of the heat through the thin tubes to the air is so much more complete than that through the thick plates of a boiler to the water, that the mechanical loss in pumping is more than compensated for?

It is further probable that some of the motion of heat under a boiler may pass into other forms of force. The most powerful means ever invented for the production of electric energy is Sir William Armstrong's hydro-electric machine, in which the electricity is collected from a jet of steam issuing from a boiler. This electricity has no doubt been generated by the action of the heat, and according to the theory of the conservation of energy, must have been the cause of an equivalent quantity of heat disappearing. This may account for another portion of the 20.52 per cent. deficit of Monsieur Lhoest.

When we consider that the temperature of the furnace of a boiler is about 2,400 deg. and the water inside the boiler say about 300 deg., it is evident that in a thick plate the molecular vibrations of the iron must be of much greater intensity on the side next the fire than on the side next the water. In fact, the condition of the section of iron lying between the fire and the water must be of a very complicated character, and one which may be studied with good hopes of leading to practical results. At all events we must not say that this proved loss of 20½ per cent. cannot be saved, until we know all the physical conditions of the flame, the plate, the water, and the steam.

We might continue these thoughts to the consideration of the changes occurring in the steam as it produces mechanical energy in the cylinder. We might trace the loss of a portion of this mechanical energy, and identify its exact equivalent in the heat of friction, which is simply the motion of the mass converted into the motion of the atoms at the surface of the rubbing parts. We might further consider the effect of the power of the engine, when allowed to give shocks and twists to different parts of the mechanism, and show that these shocks are in part converted into a form of energy which, as already described, changes the molecular condition of the material.

And do not let us imagine, because these molecular forces do not impress us with the same idea of power as the fall of the avalanche or the sweep of the hurricane, that they are insignificant; far otherwise. In order fully to appreciate this let us examine the mechanical value of the changes that occur in the atoms of 1 lb. of water passing through its various forms of gas, vapor, liquid and solid. Water is composed of eight parts by weight of oxygen, and one part of hydrogen, and is the result of their combustion. In the first stage we have the free atoms of oxygen and hydrogen, which attract each other and clash together in combustion. It has been proved by experiment, that the heat generated in burning one-ninth of a pound of hydrogen, with its equivalent of eight-ninths of a pound of oxygen, producing 1 pound of aqueous vapor, is sufficient to raise 5,833 lbs., or about 2½ tons of water, 1 deg. Fahr. We have seen, by Joule's experiments, that each pound of water raised 1 deg. in temperature is equivalent in mechanical force to 772 lbs. raised 1 ft. high. The combination of the oxygen and hydrogen to produce 1 lb. of aqueous vapor will therefore produce such a heat as is equivalent to raising 5,833 lbs. $\times$ 772 $=$ 4½ million lbs., or 2,010 tons, 1 ft. high. Professor Tyndall remarks on this amazing fact, "that it was no overstatement which affirmed that the force of gravity as exerted near the earth is almost a vanishing quantity, in comparison with these molecular forces. The distances which separate the atoms before combination are so small as to be utterly immeasurable; still it is in passing over these distances that the atoms acquire a velocity sufficient to cause them to clash with the tremendous energy indicated above." But amazing as this force is, we have not yet finished with our history of a pound of water. The atoms of the aqueous vapor now fall together to produce liquid water. The mechanical value of this act is equivalent to the raising of 333 tons 1 ft. high.

The next change is from the liquid state to the solid form of ice, the mechanical value of which act is equal to 49 tons raised 1 ft.

The total mechanical value of these three acts of one single pound of water, in the change from gas to vapor, from vapor to liquid, and from liquid to ice, is therefore equivalent to a weight of 1 ton crashing down a height of 2,392 ft.

We are tempted to retire into scepticism of these wonderful facts, accustomed as we are to judge of the magnitude of force by the effect it produces upon our senses, but the deeper we look below the surface of nature, the more shall we find that her most wonderful powers are hidden from our coarser perceptions, and only reveal themselves by the light of reason to the earnest seeker after physical truth.

Time has not permitted me to give more than a very few illustrations of the connection between physical science and engineering practice, but in all these illustrations, we see that changes in force are from motion of mass to motion of atoms, and from motion of atoms back to motion of mass. The motion of mass which we see in this world is insignificant compared with the inner motion of atoms which we cannot see. Atomic motion is the great store of force from which we as engineers must derive most of our power, and if our art is the converting of this enormous store of energy to the use of man, does it not seem to be our duty, and should it not be our highest pleasure, to study closely the co-relation of these various forms of energy?

If we, as engineers, would only study and endeavor to apply the recent discoveries in physics to our several specialties of practice, there would be little fear of the contracting effects of specializing the various branches of our profession to which I alluded in the early part of this address.

It is to the science of molecular physics that engineering must look for its future development. Amazing as the achievements of the fathers of engineering have been, we cannot study the exquisite laws which govern the different forms of energy without feeling that there are equal triumphs in store for the future, and that the true line of engineering progress must lie through those fields of investigation which surround the temple consecrated to the study of the physical sciences.

THE BESSEMER SALOON "GYROSCOPIC" APPARATUS.

From "The Nautical Magazine."

Since the philosophical toy the gyroscope was first brought under the notice of the public, proposals or suggestions have frequently been made that the seeming persistency with which it endeavored to maintain its disc in the same plane of rotation might be applied effectively to lessen the oscillations of cabins, gun platforms, and observation stages at sea.

The most important of these attempts is in the magnificent Bessemer saloon steamer, now nearly ready for sea. The original intention was to manœuvre the suspended saloon, by working or regulating controlling valves by the hand of a watchful attendant. An experimental cabin on this system, we are told, was erected on Mr. Bessemer's grounds, at Denmark Hill. In this experiment, said to have been very successful in its results, the motion of the cabin was controlled by hydraulic gear, the opening or closing of the valves, governing the admission of the water to or its release from the hydraulic cylinders, being effected by a man within the cabin; this man being guided in his movements by a spirit-level placed in front of him. The experience with this experimental apparatus showed, it is said, that it was possible for a man, by exercising constant attention, to control the movements of the swinging cabin in the manner desired; but in the practical application of the suspended cabin to a sea going vessel, it has been deemed to be strongly desirable to dispense with the necessity for constant vigilance on the part of an attendant; and hence Mr. Bessemer has been led to design the "gyroscopic" apparatus which forms the subject of this notice. In our description of this apparatus we are availing ourselves of a full account of it which appeared in *Engineering* for October 9. It is there stated that "a heavy disc or wheel made to revolve rapidly in any given plane tends always to remain revolving in that plane, and it can only have the direction of its action of rotation changed by the application of considerable force, the amount of this force depending upon the weight of the revolving body and its speed of rotation."

Here we have the word "action," evidently a misprint for "axis." As it reads, the statement is perfectly true, for it would, indeed, require a very considerable force to reverse the "action of rotation," of a 2-foot wheel running at a speed of six miles per minute; but such a statement is, in this instance, quite irrelevant. In Mr. Bessemer's specification of his patent, he says, "I avail myself of that property of matter which tends to maintain the axis of all rapidly revolving bodies continuously in the same plane, as exemplified by the rotation of a rifled shot, and still more clearly in the toy instrument known as the 'gyroscope.'"

Here again we must correct the language; the word "plane" must, we think, be a clerical error for the word "line." If we are wrong, we shall be glad, in a future article, to reconsider it as it stands. In what follows we have, however, in considering these two quotations, proceeded as if they were intended to stand as we have corrected them.

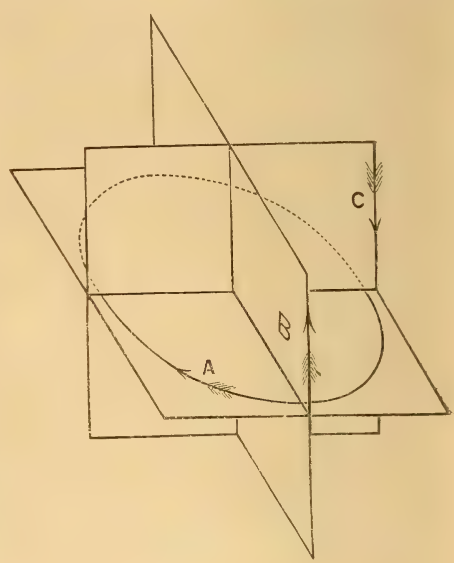
Availing himself of this remarkable "property of matter," Mr. Bessemer has constructed a monster "gyroscope" (?) 2 feet in diameter, with a rim 4 inches square, and the intention is to run it by water turbine power at 5,000 revolutions per minute, if necessary. The expectation of the inventor is that the steadying effect of this rotative energy will be sufficient to prevent the instrument from participating to any serious extent in the oscillation of the saloon; the frame of the fly-wheel being suspended upon trunnions in a line with the axis on which the saloon is suspended. The machine is connected, by suitable rods, with the valve of the hydraulic controlling cylinders; the valve is an equilibrium valve, so that there will be, as far as possible, no resistance applied to cause the steadying "gyroscopic" wheel to deviate from the horizontal.

New designs for passenger steamers, involving untried theories, so far as these may affect safety, are placed, by the express action of the Legislature, and, as we think, very properly so placed, under the immediate supervision of the Board of Trade. We do not know whether the owners of the Bessemer ship have submitted their plans to the Board of Trade, including therein their proposals and plans for this controlling apparatus. We presume, however, that the whole subject is under consideration by the Marine Department, and that, as is usual in such cases, a practical trial at sea will be required, before they give a certificate that the ship and all in her are fit and safe for the conveyance of passengers. But we have no hesitation at all in predicting that if the plans published in *Engineering*, on the 9th of October last, are authentic and correct, the general public have reason to be thankful that there is a Board of Trade, for we feel sure that a passenger certificate cannot be granted to the Bessemer ship. The apparatus is, however, so nearly complete, that there will, we imagine, be little if any advantage gained by interfering officially before the inspection services of the surveyors are applied for to test the apparatus at sea.

The first thing we have to call attention to in connection with the design published in *Engineering* is the expressed intention of running a 2-feet wheel at 5,000 revolutions per minute. Bourne says that, to provide against the effect of centrifugal force, railway wheels of malleable iron "can scarcely be considered safe at a speed even considerably under 150 miles an hour." The speed proposed for the Bessemer wheel is 360 miles an hour, and there is no provision shown to prevent even that velocity being greatly exceeded. This wheel is, we understand, to run in the saloon; there should be some way of testing it, as boilers are proved to double their working strain before the Board of Trade can pass it as safe for passengers. As no doubt the wheel is of the very best material, and as some satisfactory test may be devised and accepted, it is probable that this difficulty can be got over; but, even if the "gyroscopic" wheel can be run with perfect safety at any required speed, what then? Nothing! There would be no more steadying effect produced than if the material composing the machine were carried as pig-iron at the same height in the ship. The "property of matter" of which the inventor thinks he has availed himself, does not exist; for, as a fact, the plane of rotation of a heavy revolving disc can have angular motion imparted to it just as easily as can the plane of a stationary disc. That increased persistency of plane is induced by velocity of rotation is only an assertion, and although it is an assertion made by most of our standard authors as an assertion of a fact, and although the assertion has, we believe, never before been disputed, it has really no foundation; and it certainly will not be proved by the beautiful contrivance on board the Bessemer ship.

We sympathize sincerely with the projectors of the Bessemer saloon steamer, and we sympathize the more because we trace their mistake to standard scientific literature treating on this subject. Mr. J. McFarlane Gray, about the year 1855, attended a *conversazione* at the Philosophical Institution in Newcastle. He has informed us that he there saw, for the first time, the phenomena of the gyroscope, the large gyroscope belonging to Sir William Armstrong being on exhibition that night. He was so taken by it, that he stood beside it the whole of the evening, and the impression of that exhibition has never been effaced from his mind. He was not satisfied with the explanation given to him by the attendant, and, fortunately, he did not give up the investigation until he had completely solved all the paradoxes presented by the gyroscope. Through him, principally, other officers of the Board of Trade have become familiar with the engineering principles involved in the gyroscope. It is not the first time the subject has been officially before the officers of the Department. Our readers will probably not have forgotten that some years ago, Mr. Arthur Rigg, at the Institution of Naval Architects, asserted that the fly-wheels in Mr. Holt's engines would be a source of danger to the shafting, by reason of gyroscopic action interfering with the freedom of pitching. As there were then under construction similar engines with fly-wheels larger than any before in use, it became the duty of the surveyors to calculate the strain that would be due to the greatest probable velocities of revolution and of pitching, and they then found the moment of strain to be equal to the weight of the wheel, acting with a leverage of only one foot. This result was stated by Mr. McFarlane Gray at the meeting of the Institution of Mechanical Engineers, in the following year. That was, so far as we are aware, the first example of direct calculation of gyroscopic effect as an engineering quantity. Following out the line of reasoning as Mr. McF. Gray has stated it to us with reference to the Bessemer saloon, the seeming persistency of direction of plane manifested by the gyroscope, and supposed to operate in the flight of a rifled shot, is due to a condition that is essential to that machine, and which obtains also in the case of the rifle shot, but is by construction excluded from Bessemer's apparatus.

A gyroscope may be defined to be a



machine exhibiting a rapidly-rotating fly wheel, the axis of which has angular motion in a surface that is approximately the surface of a cone. To produce gyroscopic resistance to change of direction of plane, in a given plane, the disc must be permitted, at the same time, to tilt itself in a direction transversely to the direction in which that effort to change the plane is applied. That is, let there be three planes, A, B, C, intersecting each other at right angles, and a rotating fly-wheel with its plane of rotation in A and its axis at the intersection of B C, and, only to fix the idea, suppose the plane A to be horizontal, the plane B to be vertical, edge on to the observer, and

C to be the plane of the diagram, as in the figure.

If, while the fly-wheel rotates in the direction A, a force be applied to tilt the plane of the wheel in the direction B, a couple of equal and opposite pressures will be produced, acting in the plane C, tending to tilt the wheel at the same time in the direction C. If the plane of the wheel be permitted to move in the direction of that couple—viz., C—that motion will similarly create a couple of equal and opposite pressures acting in the plane B in the opposite direction to B. It is the misconception of this reaction that has given rise to the fallacy about increase of inertia of plane, produced by velocity of rotation. In this fallacy it is always overlooked that the resistance is associated with a motion transverse to that resistance. When the transverse motion is prevented, as in the Bessemer design, the side pressures due to velocity, acting as a couple in the plane C, being equal and opposite, just cancel each other, and when the wheel is tilted in the direction B, there will be no *work* done by the couple acting in the plane C, and consequently there will be no increase of resistance to motion in the direction B, by the velocity of rotation, and the apparatus, when so restrained, is not a gyroscope, and the material of which it is composed will act when the vessel rolls only, just as if it were so much dead weight carried as ballast. Further, when the vessel pitches the action of the apparatus will be seen to its full effect, for it will then operate to violently apply in the way to produce rolling all the power that has been provided to resist rolling, and thereby, without at all reducing the *pitching* of the saloon, add a most violent and destructive transverse motion, probably striking the stops at each side each time the vessel pitches.

Such a machine will prove to be, if it is ever tried at sea, a powerful oscillation producer, of no use when the vessel *rolls* only, and rocking the saloon to destruction when the vessel *pitches.*

We understand that Mr. McF. Gray has protected himself by patent in respect to the possible application of gyroscopic apparatus to Bessemer saloons, &c. His practical knowledge of rotatory dynamics, and his well-known inventive talent, may probably enable him to complete what Mr. Bessemer has so pluckily begun. The exact formulas, expressing the pressures, moments, and motions of the gyroscope under all conditions, are of a very simple character, and will probably now be brought before some learned society.

In amelioration of our remarks, it is proper to state that the Bessemer plans are quite in accordance with accepted engineering principles, and if Mr. McF. Gray is right—as we are satisfied he is—the circumstance of the Bessemer saloon will make his exposition of this fallacy the more striking, and cause it to be so notorious that a similar mistake can never occur again.

EFFICIENCY OF FURNACES BURNING WET FUEL.

As Determined by Experiments on a Large Scale.

BY PROFESSOR R. H. THURSTON.

From "The Transactions of the American Society of Civil Engineers."

(Concluded.)

30. The minute inaccuracy of the results thus obtained, which is due to changes of the specific heat of water, and of metal, under varying temperatures, is of no practical importance. As the vessel containing the water heated was of wood in each case, the usual correction for heating the vessel when metallic becomes of no importance also, and the weight of the thermometer being insignificant in comparison with that of the water, that correction is unnecessary. This method is of great value as a last resort, in absence of other good heat-measuring appliances.

31. The second furnace which was experimented upon by the writer was of the form known as the "Crockett." This form of furnace is shown in Fig. 2, and that here described was of the same general form as that illustrated, differing principally in its arrangement of bridge walls.

In this example two furnaces were constructed side by side, each having a grate surface of 4 × 6 feet, the total grate area of both being 48 square feet.

The grates were of cast iron, of ordinary form, set so closely that none of the wet fuel could fall through into the ash-pit. It was stated that it was not intended that the charred fuel should fall through and burn in the ash pit.

During this trial, however, more or less burning tan was continually falling into the ash-pit and burning there. This, undoubtedly, assisted in some degree in the desiccation of the wet fuel, by direct radiation of heat, and by heating the entering air as it passed over this bed of hot coals. To this extent the furnace resembled in its action the Thompson furnace, already described.

Above the grates a brick arch was turned, as shown, against which the products of combustion impinged and the heat radiated from the burning fuel on the grate, keeping this arch at a high perature, it assisted the process of desiccation of wet fuel, when first thrown in, by strongly radiating upon it the heat thus stored up while the fires were most intense. From the furnace the gases passed directly into the flues beneath the boiler.

32. The tan, wet from the leach, was charged into the furnaces through the doors in the front, as in all usual forms of furnace, and the process of "firing" differed but little from that usual with thin fires, where coal is used. The fuel was thrown in at intervals of between 5 and 8 minutes, the furnace-man taking care, first, to fill all holes in the burning mass, and, next, covering the whole with a very evenly distributed and very thin layer of fresh fuel. This fresh charge was quickly dried by the heat of the burning fuel, over which it was spread, and by the heat radiated from the hot furnace arch above it, and, taking fire, burned freely. No special effort seemed to be made to obtain "alternation" in working the furnace, but the irregularity with which the fuel burned at different parts of the grate did, perhaps, secure something of this effect.

33. The fuel was measured in the leach, as in the previous case, and about a half leach, measuring $4\frac{1}{2}$ cords, was burned during the trial, between 8 o'clock A.M. and 6 o'clock P.M. The actual working time was 9 hours, the work being stopped from 12 M. to 1 P.M.

34. The tan bark burned was hemlock, mixed with some oak. It looked like a better material than that used in the other trial. It was more cleanly ground, seemed less "soggy," and had a much better color.

35. The boilers used here were two in number. One was an old-fashioned "Cornish" boiler, 4 feet in diameter, and 18 feet long, with one 24-inch flue. The second was 6 feet in diameter, with four 18-inch flues; the total length was 15 feet. The gases from the furnace were led under the boilers, and then, with a double return through the boiler flues, to the chimney. The total heating surface, reckoned as before, was very closely 700 square feet.

36. The flues were stated to have been so long in use without cleaning, that the draught was somewhat impeded by the accumulation of ashes beneath the boilers, and that the rapidity of combustion was somewhat lessened. The two trials are, therefore, both to be taken as representing less than the maximum capacity of the furnaces.

37. The trial was made by a somewhat similar method to that adopted in the one already described. The quality of steam was determined similarly. The water was measured differently. In this case the capacity of the feed-pump exceeded several times the requirements of the boiler, and the only absolutely reliable means of determining the quantity of fuel seemed to be to measure every pound going to the pump, thus evading the uncertainty attending any attempt to secure regularity in the action of the latter.

38. A barrel was fitted to the suction-pipe of the pump, and an employee of the Mechanical Laboratory of the Stevens Institute of Technology was stationed with a hose to fill it with water, when it became empty, and to keep an account of the number of barrels used, while an employee of the proprietors of the tannery, stationed at the pump, checked the account. All of the water fed into the boilers during the trial was thus measured, and at the close of the trial the barrel was taken out, filled on the scales, and the weight of its contents determined.

39. There was no opening into the chimney flue through which the escaping

gases could be reached, and their temperature was not determined.

40. The amount of smoke issuing from the chimney of this furnace was considerably greater than was observed at the preceding trial, indicating that the Thompson Furnace secured a somewhat more perfect combustion than the Crockett.

41. The results of this trial gave the following data:

Total number of cords of tan burned 4.5
" weight of water fed to boilers 28 509 pounds.
Temperature of feed-water entering boilers (estimated).......... 160° Fahr.
Temperature of water observed in determining "priming":

	Initial.	Final.	Range.
1st observation........	68°	118°	50°
2d "	70°	118°	48°
3d "	76°	126°	50°
4th "	96°	124°	48°

Length of trial........................9 hours.

42. Estimating the priming as before, we obtain from the several observations, which were made with the steam pressure, per gauge, 55, 50, 45, and 60 pounds, respectively, x=9.02, x=8.07, x=9.12, and x=8.55, and the per centage of priming, 9.8, 19.3, 8.8, 14.5 per cent. The mean of all observations gives the average percentage of priming at 13.1 per cent., and indicates that the steam issuing from the boiler carried in suspension 15 per cent. of its own weight of unevaporated water.

43. We determine the total heat from the fuel thus:

Steam produced.28 509x0.869=24 774.32 pounds.
Water primed...28 509x0.131= 3 734.68 "

The mean pressure of steam during the trial was 50.44 pounds per square inch, and its temperature 298° Fahr. Its total heat at 298° from 0° was 1 204.8 units per pound. Then we have

Total heat, per pound of steam.............	1 204.8—160=1 044.8	
Total heat per pound of water.......... ..	298—160=138,	and
Total heat transferred from fuel to steam.	25 884 209.54 units.	
Total heat transferred from fuel to water...	515 385.84	" and hence
Total heat transferred from fuel to feed.....	26 399 595.38 units.	
Total heat per cord of wet tan....	6 866 576.75	"
Equivalent evaporation per cord, water at 212°..............	7 103.84 pounds.	
Equivalent weight of coal per cord of tan..	710.38	"

44. A sample of the fuel used in this trial was sealed up, as before, and was similarly weighed at the Stevens Institute of Technology, dried in the air one week, and its loss of moisture determined.

This sample contained 55 per cent. of water, and 45 per cent. ligneous material. The weight of the tan in the leach was judged to be practically the same as in the preceding trial, and the equivalent evaporation per pound is $\frac{7\ 103.84}{2\ 233.56} = 3.19$ plus the water held by the fuel, say 1.22, or 4.41 pounds.

45. Comparing the quantities of heat actually utilized by transfer from the fuel to the boiler, we obtain as the measure of the actual comparative efficiencies of the two furnaces 4.24 ÷ 3.19=1.33, the Thompson excelling the Crockett 33 per cent. A number of circumstances combine to make the actual difference somewhat greater than the record here indicates, but this result may probably be taken to represent practically the relative economical standing of the two furnaces.

46. Experiments on dry pine wood, made by Prof. Johnson during his extended and invaluable examination of American coals,* for the U. S. Navy, furnish a standard of comparison which will be useful here. One cord of well-seasoned yellow pine wood weighed 2,689.2 pounds —10 per cent. more than a cord of thoroughly air-dried spent tan bark—and one cubic foot weighed 21 pounds. Experiments on evaporative power showed, as a mean result, an effect equivalent to the evaporation of 4.69 pounds of water from 212°, under atmospheric pressure, per pound of wood consumed, the temperature of chimney flue being 315.2°, and the wood burning at the rate of 15.87 pounds per square foot of grate per hour, under a boiler having a ratio of heating to grate surface of 26.83 to 1.

47. Comparing this result, as a standard, with the evaporation obtained in the two wet fuel furnaces, per pound of fuel, exclusive of water, we get for the Thompson furnace $\frac{5.68}{4.69} = 1.21$, and for the Crockett, $\frac{4.41}{4.69} = 0.94$. The Thompson fur-

* Report to the Navy Department on American Coals. By Walter R. Johnson. Washington, 1844, pp. 546-550.

nace is thus seen to have given a better result per pound of ligneous combustible when burning wet tan than was obtained in the ordinary steam-boiler furnace, burning seasoned yellow pine, this superiority reaching 21 per cent. The Crockett furnace had 94 per cent. of the efficiency of the common wood-burning steam-boiler furnace.

48. The relative efficiency of fuel, comparing wet tan with dry wood, by weight, the former containing between 55 and 60 per cent. of water, becomes

$$\frac{4.24}{4.69} \times 100 = 90.40 \text{ per cent.},$$

each fuel being consumed under the most favorable conditions shown above, and equal weight of ligneous fuel being taken for comparison.

A cord of dry yellow pine, as per experiments of Prof. Johnson, evaporated 12,618.3 pounds of water. A cord of wet spent tan, burned in the Thompson furnace was equivalent to $\frac{9\,459.2}{12\,618.3} = 0.75$ cord of dry wood. One cord of wet spent tan, burned in the Crockett furnace, was equivalent to $\frac{7\,103.84}{12\,618.3} = 0.56$ cord of dry yellow pine.

49. A cord of dry yellow pine is approximately equal in heating power to 0.6 of a ton of coal, and, conversely, the ton of good coal is equal in calorific power to 1.66 cord of soft wood. An average pound of dry wood is theoretically capable of evaporating 6.66 pounds of water from and at 212.° A pound of good anthracite, similarly, should evaporate 13.5 pounds of water.

The "absolute efficiencies" of coal and wood, under the conditions already described in the several cases mentioned, are as follows: coal, 70 per cent.; wood, in the Crockett furnace, 66 per cent., in the ordinary steam-boiler furnace, 70 per cent., and in the Thompson furnace, 85 per cent.—reckoning the evaporation of the moisture in the fuel. Excluding this moisture, the percentages become respectively 70, 48, 70, and 64.

50. The data obtained at these trials are sufficiently complete to furnish a basis upon which to construct the theory of action of each furnace, and to give approximate determinations of quantities which are of importance in that connection, and of interest in their bearing upon practical deductions. The most important points are the temperatures of furnace and of chimney flue, the quantity of air supplied, and the effect of variations of area of heating surface of boilers.

51. An approximate determination of the temperature of furnace can be made, in this case, in the following manner:

The fuel used at this furnace, as taken from the leach, contained more than one-half its weight of water. In handling, it lost some of this moisture. When thrown upon the top of the furnace, and before it was thrown upon the fire, it, by its non-conducting property, prevented to some extent loss of heat, and such heat as was absorbed by it was usefully employed in evaporating its moisture. The quantity of water thus lost before entering the furnace may be estimated approximately at about 1 per cent. in handling and 3 per cent. at the furnace. Box, in his "Treatise on Heat," gives the total loss of temperature by conduction and radiation, in a fire-brick furnace, as 10 per cent. Here, several long ovens were placed side by side, and the principal loss was that from the top. Very little could take place laterally, and no heat could pass downward.

The total loss here may be taken as $2\frac{1}{2}$ per cent., which would so change the composition of the wet fuel as to leave it with 3 per cent. less water, making it about 45 per cent. combustible and 55 per cent. water.

Taking the available heat per pound of the dry portion at 6 480 thermal units, each pound of wet fuel yields 2 916 units of heat. Of this, 531.6 are absorbed in the evaporation of the 55 per cent. of water, leaving 2 384.4 units to raise the temperature of the products of combustion. Of these there are, as a minimum, 3.7 pounds having a mean specific heat of about 0.287.

The elevation of temperature is therefore 0 245.3°, and adding the mean temperature of the atmosphere, 74°, the mean temperature of furnace, assuming no dilution with unused air and no losses, would have been about 2 320°. Losing about $2\frac{1}{2}$ per cent., the temperature becomes 2 260°.

The temperature of chimney flue was found by experiment to have been 544°. The furnace gases were therefore cooled

2 260°—544°=1 716° by the loss of the heat given up to the boiler. This is equivalent to $1\,716 \times 0.287 = 492.5$ heat units per pound of gas, and to 4 049.4 units per pound of ligneous material in the fuel.

The "equivalent evaporation" from and at 212°, is $4\,049.4 \div 966.6 = 4.18$ pounds of water. The actual evaporation was equivalent to 4.24 pounds, and the difference—less than one per cent.—represents losses and errors of approximation.

52. The actual existing temperature of furnace can be thus estimated: the available heat per pound of fuel, excluding water, has been given at 2 916 thermal units. Of this $\frac{531.6}{2\,916} = 0.182$ was not useful in raising the temperature of either the furnace or the chimney. Hence, of all heat liberated, 1.00—0.182=0.818* was efficient in elevating the temperature of furnace, and 0.37—0.182=0.188 was effective in producing the observed temperature, 544°, of chimney. Then, since the same quantity of gas passes at both places, the temperature of furnace was

$$\left(\frac{0.818}{0.188} \times 470\right) + 74° = 2\,118.5°.$$

To this is to be added the slight loss of temperature, *en route* between furnace and chimney, by conduction and radiation.

53. The air supply of the Thompson furnace is unusually restricted, and has already been noted.

Instead of an ash-pit with a front entirely open, we find here closed ash-pit doors, and no other opening for the passage of air than the comparatively small orifices in the registers with which the doors are fitted. The usual amount of air supplied in furnaces burning coal is generally given as about twice the theoretically required quantity, giving a temperature of about 2 400°. In exceptional cases the air supply falls as low as one and a half times the theoretically required amount, the temperature reaching about 3 000°. In such cases it sometimes happens that the grates are melted down, cast-iron melting at between 2 700° and 2 800°.

In the Thompson furnace, with an ash-pit fire, this is very likely to take place with iron grates, and the inventor was therefore driven to the use of fire-brick grates. The mean temperature of the products of combustion is, however, lower, notwithstanding the restricted air supply, in consequence of the presence of moisture.

The quantity of air supplied is calculated as follows: the difference between the theoretical and the actual temperature of furnace, as above estimated, is 2 260°—2 118°=142°, corresponding to $142 \times 0.287 = 40.75$ thermal units per pound of gas, or $40.75 \times 3.7 = 150.8$ units per pound wet fuel, and $150.8 \div 0.45 = 335.1$ units per pound of wood, which heat was distributed through the air diluting the products of combustion.

This latter amount is sufficient to heat $(335.1 \div 0.238) \div 2\,044 = 0.69$ pounds of air from the temperature of the external air, 74°, to 2 118°. The theoretically required quantity of air, per pound of wood, is 6 pounds; hence, the products of combustion at the Thompson furnace were diluted with 12 per cent. of air: this is one-fourth that of ordinary practice with coal fires.

54. The temperature of chimney flue not being known, the estimates of temperature of furnace and of air supply cannot be so satisfactorily determined for the Crockett furnace. The following may, in the opinion of the writer, be taken as a fair approximation.

The composition of the fuel, in this case, was slightly changed in handling, between the leach and the furnace, as before. Lying in front of the furnace also, a small amount of drying must have occurred by radiated heat. Taking the total amount of both influences as producing an alteration of 2 per cent. in the composition of the fuel, it becomes 52 per cent. water and 48 per cent. dry wood.

55. The theoretical temperature of furnace gases, estimated as before, is reduced largely in this case, by the air of dilution. The fuel was burned at the rate of about 20 pounds per square foot of grate per hour, and the weight of carbon, the only valuable heat-producing element, was 5 pounds per square foot of grate per hour. The bulky character of the fuel compelled the opening of the doors, in charging the furnace, about once in seven or eight minutes. The fire burned some-

* Assuming 6 480 units as the heating power of the tan when dried, the efficiency of this furnace becomes 0.63, and 0.37 of the total heat of the fuel passes off by the chimney.

what irregularly into holes, allowing an unusual amount of air to pass up unutilized.

In ordinary practice, with anthracite coal fires, the fuel burns, with such draught as was found at the Crockett furnace, at the rate of about 10 pounds carbon per square foot of grate per hour. The doors are opened about once in fifteen or twenty minutes, and the air supply is about 240 pounds per square foot of grate surface per hour.

56. The air supply at the Crockett furnace was apparently in excess of that just given, by a large amount. Neglecting this excess, and calculating the temperature of the furnace as if the air supply were the same as with coal, the following results are obtained:

Available heat per pound wet tan..	3 110.4	units.
Rendered latent by evaporating 52 per cent. water	503.6	"
Effective in elevating temperature..	2 606.8	"

This was distributed through 12.5 pounds of gaseous products of combustion, of a mean specific heat, 0.25. The elevation of temperature was therefore 832.8°, and, adding the mean temperature of external air, we obtain for the average temperature of gases escaping from the furnace, including cold air streaming through the furnace doors and the holes in the fire, 919.3°, or about 100° above the temperature at which combustible gases can take fire.

Taking the air supply as possibly at times as low as that considered the minimum with ordinary coal fires, 180 pounds per square foot of grate per hour, where burning fuel with sluggish draught, the temperature of furnace at such times becomes 1 150.3°.

57. The temperature of chimney flue may be readily estimated for these conditions. Referring the performance of this furnace, like the preceding, to "dry wood" as a standard, its efficiency is 47 per cent. Hence 53 per cent. of the heat obtainable from the fuel passes off by the chimney. The loss of heat by the escape of unburned carbon, in the form of smoke, although more than at the other furnace, was not probably sufficient to be here taken into account. The following are the estimates:

Available heat per pound of wet tan	3 110.4	units.
Passing up chimney, 53 per cent...	1 648.5	"
" " latent in vapor	503.6	"
" " elevating temperature	1 144.9	"

This was distributed throughout 12.52 pounds of gas where the usual supply of air was maintained, and through 9.64 pounds in the case of less free supply, supposed possible at times.

The heat per pound of gas amounts to 91.4 units for the first case, elevating the temperature $91.4 \div 0.25 = 365.6°$ above that of the atmosphere, or to 452°.

Under the other supposed conditions, the elevation of temperature of chimney becomes 467.7°.

To secure an economy at this furnace equal to that obtained at the Thompson furnace, it would be necessary to reduce the quantity of heat carried off by the chimney gases in the proportion of 53 to 37.

One-third of this heat is latent in the vapor of water, and no part of that can be secured. The requisite reduction of temperature of gases to effect this economy is thus exaggerated; and it would be necessary, were such a thing possible, to bring down the temperature of chimney to between 140° and 160°, to a temperature 160° or 140° below that of the boilers itself, or to less than one-fourth that required for most efficient draught.

58. In determining the precise value of two competing sets of apparatus, as generators of heat, it is necessary first to obtain from each its best performance in producing heat, and then to provide means of absorbing and utilizing that heat with equal thoroughness in both cases.

The proper area of heating surface of boilers will therefore vary with each case. The same area, where the furnaces themselves differ considerably, may in the one case allow a waste of heat, while in the other it may reduce the temperature of gases so far as to compel the adoption of a "mechanical draught." In the cases here considered, the area of heating surface was fortunately very nicely adapted, in each instance, to the requirements of the case. In both examples, the temperature of chimney flue is found to be somewhat below that required for most efficient draught, but was not far different in the two cases, the less economical furnace having the economical advantage of such difference as did exist.

The trial, therefore, exhibits very fairly the intrinsic values of these two furnaces as heat-generating apparatus, and of these two radically different methods of working them as taken apart from the efficiency of heat-absorbing or heat-utilizing contrivances.

59. The importance of high temperature of furnace is strikingly and beautifully illustrated by these results. The two furnaces develop practically the same amount of heat from the fuel, but the one distributes it through a large volume of gases at low temperature, sending a considerable proportion of it up the chimney, while the other raises a small volume of gas to a much higher temperature, making it more available to the extent of 33 per cent., and finally, even then, sending up the chimney gases of higher temperature than the first.

The abstract *efficiency of the furnace*, in any ordinary case, is represented by the formulæ—

$$e^1 = \frac{t_1 - t_2}{t_1 - t_3} = \frac{T_1 - T_2}{T_1 - T_3}.$$

Where e^1 represents the efficiency and t_1 and t_2 are the absolute temperatures at which the heat is generated, and at which wasted heat is discharged, and t_3 that of the external air, T_1, T_2, T_3, are temperatures on the Fahrenheit scale.

In these cases

$$e^1 = \frac{2\,118° - 544°\ \text{F.}}{2\,118° - 74} = 0.77.$$

$$e^{11} = \frac{919° - 452°}{919° - 86.5} = 0.56.$$

60. These values do not represent the *efficiency of the fuel*, including the vaporization of water contained within itself. In these cases the heat lost, as latent in vaporization, before the generation of these temperatures, is to be deducted to give the total efficiencies of the fuel, which thus are found to have the values of 0.77 (1—0.182) = 0.'63 and 0.56 (1—0.175) =0.46.

The experimental determinations were 0.64 and 0.48, if referred to seasoned wood, and 0.63 and 0.47 when referred, as here, to dry wood of a calorific value of 6 480 heat units.

To make the values of e comparable with the standard already assumed for *final absolute efficiency*, per experiment, it is necesary to add 9 per cent. to the first values of e, in each case, in order to credit the fuel with the heat used in the vaporization of its water, and with the heat carried by the vapor up the chimney.

Thus the values 0.77+0.09=0.86, and 0.56+0.09=0.65 are deduced. These ratios, by experimental determinations, were 0.87 and 0.67. The correspondence of these figures with those just deduced theoretically is a remarkably conclusive evidence of the accuracy of the estimated temperature and of the fact that the difference of efficiency found by trial is due to such difference of temperature. The accordance is unusually precise.

61. Rankine has given a formula* for determining the efficiency of fuel in ordinary steam boiler practice, where the ratio of the area of heating surface, and of fuel burned per hour, to the square foot of grate surface, is known:

$$\frac{e^1}{e} = \frac{B\,S}{S + A\,F},$$

in which $\frac{e^1}{e}$ is the quantity called above e^1, A and B are constants, and F and S are the ratio of fuel burned per hour to the square foot of grate, and the ratio of area of heating surface to grate area.

For the cases here considered $A = 0.5$, and $B = 0.92$, $S = 8.5$ for the Thompson, and 14.5 for the Crockett furnace, $F = 1.38$, and 5.3: $\frac{F}{S}$ becomes 0.13 and 0.36, and the value of $\frac{e^1}{e}$ is, for the Thompson, 0.859, and for the Crockett furnace 0.776.

Were this formula applicable to these cases, the experimental determinations of efficiency should coincide with these, but they are 0.64 and 0.48. This difference is a consequence of the facts that the fuel used in these furnaces was wet, and that the large proportion of heat absorbed by the water was so much abstracted from the efficiency of the fuel. Thus the absolute values are reduced.

They differ, also, in consequence of the important fact exhibited in the preceding paragraphs, that the temperature of furnace differs in each case (and in the case of the Crockett furnace immensely), from the temperature, 2 400°, given by Rankine as the mean temperature of furnaces to which his formula is adapted. This changes relative values.

* "Steam Engines and Prime Movers," p. 292, § 4.

The value 0.859, for the Thompson furnace, is almost precisely that obtained by experiment—"including water in fuel," 0.86—as it should be, since the temperature of that furnace, 2 118°, is not far different from that of the ordinary coal fire. The value, 0.776, for the Crockett furnace differs greatly from that formed by experiment—"including water in fuel," 0.67—as would be expected in consequence of the exceptionally low temperature of that furnace.

The difference between these two theoretical values, 0.859 — 0.776 = 0.083, would represent approximately the loss of total absolute efficiency that might be expected were the case one of ordinary practice, and were the Thompson furnace supplied with boilers of as small a ratio of heating surface to fuel consumed, $\frac{F}{S}$ as the Crockett furnace actually had.

The difference which would really be produced would be less in consequence of a circumstance peculiar to that example, of which the influence has not been noticed by writers on this branch of the theory of engineering.

62. The rate of conduction of heat from the furnace gases to the heating surfaces with which they are in contact varies, in some not well determined ratio, with the difference of temperature. It may be represented approximately, according to experiments of Charles Wye Williams,* and judging from the analysis of M. Paul Havrez,† by a hyperbolic curve of which the equation is $x\,y = A$, y representing the evaporation for a unit of area of a tube at a distance x from the furnace.

$U = B \log x$ is the equation of total evaporation.

When the volume of gas is the same, as in cases to which the formula of Rankine applies, the constants in these equations are the same, and his formula gives a remarkably satisfactory approximation. Where, as in the Thompson furnace, the restriction of the air supply causes a comparatively slow movement of gases along the heating surface, the value of that portion nearest the fire becomes enhanced, leaving the furthest portions of less efficiency.

* "On the Steam Generating Power of Marine and Locomotive Boilers."—London, 1864.

† "Evaporisation decroisante en Progression, Geometrique dans les Chaudieres."—Revue Industrielle, 1874.

The effect of reducing the air supply nearly one-half would, therefore, be to actually reduce greatly the amount of the theoretical loss, 0.08, just given. The real loss would be somewhere between this 8 per cent. and the smaller differences noticed between the theoretical estimates of efficiency of fuel and the actual differences shown by experiment. This latter consideration may, perhaps, be taken as a proof that this difference of efficiency due to such a change of heating surface, would amount to approximately 2 per cent. Were more steam wanted, this would be at once sacrificed at the Thompson furnace, to bring the temperature of chimney up to that, 645°, which would give most efficient draught.

63. At the Crockett furnace, the effect of the exceptionally low temperature of furnace is to equalize the value of heating surface; and the considerable velocity of the gaseous current, which is a consequence of the unusually great volume of air passing through the furnace, increases this effect. The nearer surface is inefficient, and the most distant portions of the heating surface are therefore proportionally much more efficient than in the preceding case.

Extension of surface is, however, precluded by the fact that the temperature of escaping gases would fall still further below that required for effective draught, and, as already indicated, were it possible to operate the furnace at all, this temperature would become one-half the temperature of the boiler, were so much heat abstracted as to give an efficiency of fuel equal to that obtained in the other furnace. Heat would then pass from the boiler to the gas at those portions of its surface furthest from the fire, and the draught could only be maintained by means of special "blowing" apparatus. This is another fact illustrating the importance of high temperature of furnace in the attainment of high furnace efficiency.

64. The following table presents the results of the above investigation in a concise form, in which it may be found very useful for reference.

65. Both of these furnaces were introduced about twenty years ago, and the first is in somewhat extensive use. No experimental determination of their actual relative efficiencies has ever been made

RESULTS OF TRIALS OF FURNACES BURNING WET SPENT TAN BARK, AUGUST, 1874.

KIND OF FURNACE.	Fuel.	Percentage.		Total weights pounds.			Steam.	Priming.	Percentages.		British thermal units per cord of tan.	Apparent evaporation.				Actual evaporation.		Ratio of air supply to theoretical.
		Water.	Combustible.	Fuel.	Combustible.	Feed.			Priming to feed.	Priming to steam.		Per cord fuel.	Per pound combustible.	Per sq. foot grate per hour.	Per sq. foot heat surface per hour.	Per lb. of fuel.	Per lb. combustible.	
Thompson.....	Tan.......	59	41	44945	17198.41	73125	68393.8	4731.2	6.47	6.92	9143321.4	9596.75	4.25	23.7	2.81	1.3	3.98	1.12
Crockett......	Tan.......	55	45	22336	10051.20	28509	24774.32	3734.68	13.1	15.	6866576.75	6335.33	2.83	65.9	4.52	......	2.46	8.
Ordinary steam boiler	Pine wood.	....	80	......	2360.50	......	....	....	......	......	....	10891.26	4.05	61.5	2.29	4.05	4.03	......
Ordinary steam boiler	Anthracite coal	....	91	......	....	......	....	....	......	6.	....	....	8.75	95.	3.00	7.35	8.75	2.

KIND OF FURNACE.	Approximate estimate mean temperature of furnace gas, Fahrenheit.		Equivalent evaporation per 212° F. per lb., including water in fuel.	Equivalent evaporation from 212° F. per lb., excluding water in fuel.	Relative efficiency, excluding water in fuel—Crockett =1.	Relative efficiency, excluding water in fuel—wood=1.	Relative efficiency, including in account water in fuel — Crockett= 1.	Relative efficiency, including water in fuel—wood=1.	Absolute efficiencies, water in the fuel			
									excluded		included, dry wood as standard	
	Furnace.	Flue.							Standard of 6385 units.	Dry wood of 6480 units.	of 6385 units.	of 6480 units.
Thompson...............	2118°	544°	5.68	4.24	1.33	0.90	1.29	1.21	0.64	0.63	0.85	0.86
Crockett................	919°	452°	4.41	3.19	1.00	0.68	1.00	0.94	0.48	0.47	0.66	0.67
Ordinary steam boiler	....	....	4.69	4.69	1.47	1.00	1.06	1.00	0.70	0.70	0.70	0.70
Ordinary steam boiler	2400°	700°	10.50	10.50	3.28	2.23	2.37	2.23	0.70	0.70	0.70	0.70

before, so far as the writer is aware, which has enabled their theory to be worked out. The determination of their theory, as here given, has greatly interested him, and will, perhaps, prove as interesting to the profession. It may be found of value, in view of the many important applications which are daily being made of the various kinds of wet fuel.

The temperatures, as given, may be somewhat below actual temperatures where they are determined from the composition of fuel, as the calculations are made on the assumption that all vapors issuing from the fuel are raised to the mean temperature estimated. The real fact is, that they are expelled while the temperature of issuing gases is reduced by their presence, and they therefore do not abstract as much heat as is debited to them in the calculation.

During those intervals of time which elapse between the drying of one charge and the introduction of the next, the temperature of furnace rises to that due to the combustion of dry fuel. The results, as given, are probably, however, practically and sufficiently correct.

ON SOME DIFFERENCES BETWEEN BRITISH AND AMERICAN ARCHITECTURAL PRACTICE.*

By WILLIAM FOGERTY, F. R. I., B. A.

A RESIDENCE of over two years in the United States, during which I have visited the principal cities and become acquainted with many of the leading members of the architectural profession, having previously spent the greater part of my life in the study and practice of architecture in the United Kingdom, has brought fully before my mind many important differences in the systems of practice prevalent in the two countries, the consideration of which may not be unworthy the attention of this Institute. The differences I refer to are not such as relate to modes of construction, employment of material, or artistic style, but have reference to the business relations between architects, clients, and contractors, rates of remuneration, measures of responsibility, and such like, constituting what may be called the economic aspects of the profession, apart from the scientific or æsthetic, and as such may be conceived as of great importance in themselves, and as presenting peculiar advantages for comparison, with a view to the adoption in one country of what has proved advantageous in the other, or the rejection in one of what has been found objectionable in the other.

I am very far from assuming, as one would suppose to be the case with many who have written on this great country and its institutions, that because of the youth of the nation, therefore it must be content to remain behind in many things, or in other words, that it is not as yet sufficiently developed or educated to avail itself of every improvement, general or special, which has been proved and found desirable in Europe. I have heard this idea broached as often by native Americans as by Europeans, but from whoever it originates, I disclaim all sympathy with it. On the contrary, I am convinced that there is no invention or improvement in the whole compass of modern civilization for which this country is not ready, and which, if it be really an improvement, will not meet with recognition proportioned to its value. The experience of the past, short though it be, fully bears me out in this view. So far from being disposed to remain behind Europe in the practice of any art, science, or business, the disposition of the American people is, if I judge it rightly, to advance beyond the older portion of the world; and in pursuance of this noble ambition, as every unprejudiced person must admit, they have often enough succeeded; for it is easy to point to many things that are far better contrived, ordered, and settled here than in Europe. Nor are such things to be looked for outside the limits of the architectural profession. Many improvements, both in design and construction, are to be found in American buildings, for which, as yet, we look in vain in Europe. And even if we confine ourselves to the limited aspect of the profession contemplated by the present paper, we find that in some particulars the condition of the profession

* Read at meeting of the N. Y. Chapter of the American Institute of Architects, Tuesday, Dec. 1, 1874.

is rather better here than there. For instance, the frantic and disgraceful struggles called architectural competitions are neither so numerous nor yet so humiliating as in England. Every time a church, school, or other quasi-public building is to be erected, a score or two of architects are not found ready and willing, as in England, to prepare elaborate and costly designs for it, on the bare chance of one of them getting the job and earning thereby a few hundred pounds or thousand dollars. Architects' assistants and draughtsmen are also somewhat better paid here than in England, though not as much in proportion as mechanics or other skilled helps. But when we have mentioned these two more favorable conditions, we have nearly exhausted all that exist, though not, let me hope, all that will soon be developed, when the really advantageous position which ought to be occupied by the architectural profession, in so great and growing a country, is better understood.

Certainly, if we compare the amounts expended on buildings in this country with the corresponding amounts expended in England, the advantage would seem to be enormously on the side of the American architects. I have carefully observed the amount of work doing in several of the great cities, and am well satisfied that there is at least as much actual building doing in the United States as in the United Kingdom, but that the amount of money expended in this amount of building is on the average about three times as great. The difference is not so noticeable in small works, and the general use of wood in country houses tends to lessen it; but on the other hand, the use of brick, stone, and iron has become very general of late, and when we come to deal with structures where these materials are employed, the disproportion is enormous. I have little hesitation in saying that substantial buildings cost, on the average, five times as much here as in England. For instance, a first class city church, bank, newspaper, or insurance office, that would cost $500,000 here, could be well built for £20,000 there. Nor does this enormous difference of cost seem to have any effect in lessening the number of costly buildings to be erected. The American public seems determined to have great and noble buildings, at whatever cost—a resolve which should be at the same time honorable to the nation and advantageous to the architects. I know of only one building now in progress, in the whole British Empire, on which the expenditure, after years of discussion, has been authorized to reach a million of pounds, and yet I could name half a dozen buildings in progress in the United States on which the expenditure is likely to reach three and even four millions of pounds. Whatever, therefore, may be the relative condition of the profession in the two countries, the public that has to be served is enormously more lavish in its expenditure on this side than on the other. Yet I fear that, whoever may reap the benefit, but a very small and undue share of this lavish expenditure must find its way into the pockets of the architects.

For when we come to compare notes as to the actual condition of the profession in each country, the advantage, apart from the two particulars previously noted, would seem to be altogether on the British side. First, the profession is much more numerous there than here. About 150 architects' names appear in the New York business directory for a city of one million inhabitants, while London gives about 1,000 to a population of three-and-a-half millions. Even this comparison should be adjusted, for the London and New York architects are not so much dependent on their respective cities as on the country at large, and I need scarcely say that the population of the United States is considerably greater than that of the British Isles. And, leaving numbers out of the question, let us compare the incomes realized as far as they can be judged. The profession of architecture is not a particularly lucrative one anywhere, but nevertheless, I think among its members indications of well-being are more manifest in England than in America. The leaders of the profession there, who are generally noted by having the somewhat doubtful honor of knighthood conferred upon them, have also commonly realized adequate fortunes or incomes, and, in a fair number of cases, have sat in Parliament and become chairmen or directors of banks, railways, and insurance companies. And the men in good practice, next to them, generally manage to keep up as good establishments as the men of same rank in other liberal professions. I must say I have heard very few cases of fortunes made by architects in America.

Among the numerous biographies of self-made men, which form so large a part of the popular literature with which "young America" is regaled, I find merchants, manufacturers, lawyers, doctors, contractors, engineers, builders, store and hotel keepers in abundance, who, in greater numbers than in any other country, have risen from nothing to affluence, but rarely if ever have I found mention of an architect of whom the same can be said. The only remarkable case I can call to mind is that of the late John Kellum, whom, as I am informed, this Institute would not admit to its membership. It can hardly be doubted, I think, that in this country architects are not much appreciated. Those of them who occupy public positions, even though charged with the direction of enormous and costly structures, which cannot be rivalled in these respects in Europe, are yet paid salaries which, when the high price of living is considered, amount positively to a bare subsistence. The architect of the United States Treasury in Washington, directing an expenditure of from ten to twenty millions of dollars annually, and conducting what is undoubtedly the largest architectural business in the world, receives the magnificent sum of $4,000 a year. The State of New York is a little more liberal to the architect of the new Capitol—one of the greatest architectural works the world has ever seen—and allows him $10,000. Compare these with the salary of the architect of the City of London, who has only to attend to the buildings undertaken by the Corporation of that one city, and receives £3,000 a year, besides a liberal extra allowance whenever special arrangements have to be made for the reception of a Sultan, Shah, or Emperor. Although Sir Charles Barry considered himself shabbily treated, he received 3½ per cent. on about two millions of pounds for the new Houses of Parliament, and the vigorous remonstrances made by the profession on that occasion secured that in all future works of like magnitude, such as the Government offices and the Law Courts, the regular rate of five per cent. has been adhered to. A still more significant example of the slight esteem in which architects are held here is to be found in the notices of public buildings by the press. Rarely if ever is the architect's name to be found in any of these. The committee, contractors, superintendent — anybody is deemed worthy of special mention but the architect, whose share of the work is not considered worth mentioning. Intelligent Americans, both at home and abroad, are not slow to boast of the great structures to be found in this country, such as the Capitol and other public buildings at Washington, but not one in a hundred seems to know who were the architects of these great works, or if he does happen to know, to think anything remarkable about them as having exhibited genius, skill, or taste of which the country might be proud. Not so the merest ragamuffin in the streets of Florence or Vienna, who knows all about Michael Angelo and Palladio; or the youngest schoolboy in London, who knows St. Paul's and the London churches as the works of Sir Christopher Wren. The material elements of a building, its dimensions, the amount of granite or marble used in it, and especially the number of millions of dollars it has cost, are considerations to which the American mind is fully alive; but the mental or artistic element, the brain work involved in the design, and particularly the man who supplied this brain work, are matters apparently regarded with supreme contempt and indifference.

And yet this takes place in a country by no means ungrateful to her great men or humbler intellectual laborers in other fields. The names of the founders of the Republic, of the signers of the Declaration of Independence, of the generals, admirals, and statesmen who have adorned its history are as much honored here as are those of the corresponding men of other countries. American authors do not reap their full pecuniary reward, chiefly because of the absence of an international copyright, but receive their full share of honor at all events. American painters, sculptors, and musicians have no cause to complain of want of appreciation by their countrymen, nor will either the incomes earned by or the consideration accorded to the members of the legal and medical professions suffer by comparison with the same in England.* Architects seem to stand almost alone in the experience of neglect and even contumely in a country where their services ought to be more in request and more highly valued than in any other.

A very little observation and comparison will show that architects are much more extensively employed in the old country than in the new. Scarcely any building is undertaken in the United Kingdom without one. A sensible man there would think as soon of going to law without a lawyer as of building without an architect. In this country, however, nothing is more common than to see large and costly structures erected without any, the business being done or rather usurped by some boss mason or other contractor who succeeds too often in persuading the proprietor that he can do better than any architect, which would certainly be true if his own profit and interest were the only matters to be considered.

The Rev. Dr. Osgood, a well-known and warm friend of the profession, in the address which he gave to the New York Chapter about a year ago, admitted pretty much what I have stated above, when he alluded to there being "trouble between the American public and the architects." And as one of the means he prescribed to remove this trouble was that architects should use their pens more, I will endeavor so to use mine as to trace out some of the causes which bring the profession in this country into disrepute, and by comparison with the older country, to point out some of the means by which its status may be improved.

The chief element in the want of appreciation shown by the American public towards architects is to be found in the ignorance which prevails as to what the proper functions, responsibilities, and remuneration of architects really are or ought to be. A general idea of course prevails that architects "draw plans," but beyond this the most profound ignorance will be found to prevail. If we can only succeed in removing this ignorance, a vast deal will be done towards removing the evils which follow from it.

I have already alluded to the disgracefully keen struggles which take place in England over every public building thrown open to competition; but this after all is only one instance of the overcrowding in every branch of business which prevails there, and proves that at any rate the position of architect to any public building is something worth striving after, and it really is so, because once appointed to that position, the duties, responsibilities, and emoluments are understood and admitted as a matter of course. Here, on the contrary, once a design is selected, the architect has to enter on a series of discussions as to what further he is to do in reference to it; whether he is only to furnish the plans, or whether he is also to superintend, and in what way, and at what rates; if there is to be a superintendent besides the architect, and if so, whether he is to act over or under the architect. If it be settled that the architect is to be paid a commission, and the rate of that be settled also, a third question arises also as to what amount it is to be charged upon; whether upon the whole, half, or two-thirds of the cost of the work. That such questions can and do arise indicates, as above stated, a deplorable amount of ignorance on the part of the building public; but it indicates more; namely, a vast deal of neglect and irregular practice on the part of the profession. It ought surely be the business of the architects, individually or collectively, to enlighten the public on all these questions; for if not, who else is to do it? A proper code or system of practice is needed, towards which the Institute has certainly made some approach, but this will be of no avail so long as the profession generally do not adhere to it in practice. The functions, powers, responsibilities, and charges of architects need first to be thoroughly understood and agreed on among themselves, next to be made known to the public in every possible way, and thirdly to be fully and honestly acted up to by the profession. When these three conditions are fully complied with, it will be seen whether the public will not accord a larger amount of respect to the profession than ever it has done hitherto.

* Professor Erichsen, one of the most eminent surgeons in England, who has recently visited this country, and lectured on the condition of the medical profession in it, is of opinion that that profession enjoys a higher degree of social status and consideration in the United States than in any other country.

In considering such a code or system of practice, the profession in this country ought to be possessed of a great advantage in having all the experience of the old country to guide them. Up to the present it would seem as if this Institute had been very much disposed to follow that example, for I observe the brief scale of charges issued by it agrees in the main with that of the British Institute. It however differs in being much briefer and less definite, the former of which would be an advantage if it did not involve the latter. Brevity is highly desirable if it be not attained at the expense of clearness. Now the scale of charges of the American Institute makes no mention either of a surveyor or superintendent (or clerk of works), thereby ignoring or leaving in doubt two most important points in architectural practice; namely, accurate estimating and proper supervision. Now, my observation during the period referred to above has led me very strongly to form the opinion that the total neglect of one of these points, and the irregular manner in which the other is performed, are among the most powerful causes that have contributed to make the profession at large to enjoy so little of the confidence of the American public; and I therefore propose to consider these subjects in detail more fully further on.

If the American architects could succeed in getting the same rates of charges generally adopted here as in England, the profession ought certainly be a very lucrative one, for, as already observed, the cost of building is so much greater. To take the examples already quoted, a church or other first-class building for which the architect would receive £1,000 in the old country, he would get $25,000, or nearly £5,000, for here. And yet he would have no more to do in one case than in the other. To be sure he would have to pay his assistants a little higher, perhaps twice as much as the same class of men receive in the old country, but this is almost the whole difference. The wonder is, then, that with such a scale of charges apparently in general use, the architectural is not the most lucrative profession in the country. But a little further inquiry will soon show that the attempt to establish the same rate of charges here as in England has not succeeded, and that, as a general thing, no such rates are paid unless on frame or other small buildings, where the outlay would not be much greater than on similar buildings in England. And I think the American public can hardly be blamed for hesitating to pay New York architects four or five times the actual money for the same services as is paid to London men, merely because it amounts to the same rate per cent. And I question whether this high rate being so publicly put forward, although privately departed from, does not frighten the same public from having anything to say to architects at all, and thereby defeats its own object. Certainly it has been noticed more than once, that the architects who have habitually worked under that rate have done well, but that those who have persisted in adhering to it have done but indifferently or worse. I respectfully suggest, therefore, that unless it is to include more than what is ordinarily included in England, the five per cent. may be too high a rate for an architect's services on such buildings as those referred to, and might possibly, with advantage both to the profession and the public, be reduced.

It is commonly urged in defence of the attempt to set up the same rates of charge here as in England, that the cost of living is so much greater here than there as to justify it. But this is not by any means clear. House rent, clothing, and a few other items cost more, but the difference is not such as to justify architects in asking so very much more for their services than their English brethren get. The medical and legal professions do not ask four or five times the fees of their British confreres. It need scarcely be observed that the judges, cabinet ministers, and other high officials, get much less than the corresponding functionaries in the old country. But supposing the statement as to the cost of living were admitted, then the means adopted to meet the increased expense are very unfortunate, for the effect, as above pointed out, is greatly to limit and circumscribe the employment of architects, and cause them to realize much less incomes on the whole than are attained by the members of the same profession in the old country.

It may, however, be worth considering whether it is not better to keep to the time-honored rate, but to make it include, not only all that is included in England, but also some things that in England are considered additional matters, although incidental to an architect's employment. And I am not clear but that this was the idea of the original framers of the American scale. At least, such is the plain meaning of it as it stands. The first clause reads, "In full professional services (including superintendence) five per cent. on the cost of the work." Passing over the possibility of an architect's having to prepare several designs for the same work, for which the English scale specially provides an extra charge, and for which the American one makes no provision, let us inquire what would any intelligent client understand by this? Would not he at any rate understand that the architect was bound to superintend fully? and would not he justly consider that a demand on the part of the architect for a local superintendent, to be paid by the client, in addition to what he pays the architect, was highly unreasonable? And yet I have heard and read loud complaints from American architects because clients will take this view. I think it a great matter of regret that there should be any misunderstanding on such an important subject, and that it issues either in the architects attempting to carry on their works without competent local superintendents, or that the clients will insist on having such, but make a deduction from the architect's fees on that account, and too often transfer the confidence which should be given to the architect to the superintendent instead. In fact, instead of working harmoniously, as do the English architects and their local superintendents, or "clerks of works," as they are called, the American architects and superintendents are commonly to be found arrayed in hostility against each other. And I hope I will be pardoned for saying that I fear the chief blame for this unsatisfactory state of things rests with the profession. For surely the idea that the architects themselves, by making occasional visits, can fully and properly superintend works of any consequence, whether in their immediate neighborhood or perhaps miles away, is downright preposterous. Most clients regard it as such; and, if there be no other superintendent than the architect, expect, and with reason, to see him at the building every day. Of course the client is disappointed in this expectation, and finds that what he and his architect meant respectively by "full professional services (including superintendence)" were two different things. Unless he is satisfied to have his work scamped, he will insist on a local superintendent forthwith, on account of whom the architect's fees are reduced, and who, feeling that the architect would have done without him if he could, too often begins to do his best to oust the architect and supplant him in the confidence of the employer. This is clearly a most objectionable state of things, and can only be remedied in one or the other of two ways; viz., either by the architects honestly undertaking to do by deputy what they cannot do in person, and providing competent local superintendents, appointed and paid by themselves (which I believe they could well afford to do if they get the five per cent.), or by a clear distinction being drawn between the general superintendence, which the architect can give himself, and the close and constant supervision by a local superintendent, and by the client being at once advised that the first is all that he can expect from his architect, the second he must pay for in addition. This latter is, as is well known, the English system, and is clearly enough stated in the English scale; and if it be thought desirable to have the same adopted here, it should also be stated in the American scale. I doubt very much, however, that the American public at large will ever agree to pay architects five per cent. and pay superintendents in addition; and I would recommend in preference, to keep to the existing scale, but act on it in its full meaning, and let the architects of all important works provide competent local superintendents paid by themselves and responsible directly to them. This would go far to gain the confidence of the clients, and reconcile them to the payment of the five per cent., and I am informed has been the practice of some of the most successful men, both in New York and Boston. Anything almost would be better than to have noble designs murdered in their execution for want of proper supervision, or to have architects ousted from a most important part of their business by the rivalry of hostile superintendents, thereby reducing them to the level of mere draughtsmen.

There can scarcely be a more dangerous rock for the architectural profession to split on than this; for not alone is the superintendence of their buildings likely to be taken out of their hands, but also the selection of contractors and control of building operations generally. In this respect the practice here contrasts disadvantageously with that of the old country. There the whole business of getting tenders and arranging contracts is done under the architect's direction, it being a settled principle that none but contractors with whom he is satisfied shall be employed. Here, I regret to observe, selections of the same kind are made without any reference to the architect, and often enough, in consequence, contracts for large works are awarded to scoundrels destitute alike of principle, capital, or credit, from whom the architect may as well expect to get good work as to bring any other clean thing out of an unclean. And it may easily be observed that no matter how little the architect may have had to do with the selection of the contractor, and how honestly he may have endeavored to compel the proper execution of the work, he is held fully responsible, both legally and otherwise, for whatever failings or defects may be found to exist in it.

The next important point of difference between English and American practice has reference to the preparation of estimates, and is of the utmost consequence as affecting the credit of the profession. I think there can be but little doubt but that the American public has little or no faith in architects' estimates. The report of Governor Dix to the Legislature of New York contained most severe strictures on the profession in this respect, and whether fully justified or not, his remarks were extensively echoed by the press, and I am not aware that any satisfactory answer or explanation was ever given on the part of the profession. And if we look into the matter and compare notes, we find that this is unquestionably a neglected matter by American architects. The manner in which estimates or bids for works are obtained in chief cities of the United States is still the same as it was in England fifty years ago, and may lawfully be characterized as unsystematic, wasteful, and inaccurate. It does not seem to be usual to have any calculations made on the part of the owner or architect as to the amount of work requisite to carry out a design, or the prices that work is likely to cost, until actual bids or tenders are required. Architects' estimates, therefore, are very seldom made at all, and what pass for them would be more properly described as architects' guesses, not being the result of calculation. When tenders are asked for, accordingly, neither the architect or owner has commonly any but a very hazy idea as to their probable amount, and the extent to which that may be affected by any particular item in the design or specification. The drawings and specification are placed before a number of contractors, who commonly take up a deal of the time of the architect and his assistants, as well as a deal of his office room, while engaged in overhauling them, and making out their calculations, and unless the architect has his drawings lithographed, so as to be able to supply each contractor with a copy, a vast deal of delay and inconvenience occurs in lending out the drawings to one after the other. When the bids or tenders come in, they only appear ordinarily as lump sums, for the contractors are very chary of allowing their detailed calculations to be seen, and with good reason, for any that have yet come under my notice exhibit the most surprising discrepancies and absurdities, and it is therefore easy to understand why they should be so sedulously kept out of view.

Before reviewing other defects in this system I may first observe that it is evident a large waste of labor is involved in the fact that each contractor has to calculate the quantities of work for himself, a business which might just as well be done by one for all, and a very complex matter if properly done, but which of course may be slurred over or jumped at if men prefer to do so. The fact that contractors, are found willing to incur all this unnecessary trouble is no defence for the waste it involves. At present it is the only means they have of obtaining contracts, and must be submitted to, but of course it must be paid for in some way and come out of somebody's pocket. Architects may fancy it is no affair of theirs, because the contractors are willing to put up with it, but this principle, if generally acted on throughout the world, would forbid all improvements by which waste is stayed or economy effected. A steamship, railroad, or telegraph company, for instance, which would neglect any means by which waste could be stayed, merely because the public or shareholders, not having any other resource, had to put up with the result whether on the rates or dividends, would be guilty of gross unfaithfulness either to the shareholders or public, possibly to both. If the architects are to be really what they are nominally, the "master-builders," it is their duty in the interest of the building public to make such arrangements as will prevent waste of all kinds, and thereby popularize as much as possible the business in which they are engaged.

Apart from this, a set of tenders only in lump sums is unsatisfactory: first, because it gives no security against collusion; and secondly, because it gives no aid towards revision and adjustment, should it be found, as so often happens, that the amounts exceed the prescribed limits. It does not by any means follow that because a set of tenders differing not very widely are received for a work, that its proper value has been reached. The often hasty and irregular manner in which the quantities are calculated, as above described, may reasonably be expected to issue in mistakes, through which a man whose prices may be lowest, and facilities for executing work are the most advantageous, may be at the top of the list, and *vice versa.* Caucuses and combinations may be, and, if I am rightly informed, often are found amongst contractors by which they agree on whose bid is to be the lowest, the rest putting in at a small sum over it. Again, there may be items in the work which cost more than they are really worth to the design, and which, if the architect or owner knew the cost of separately, they would be glad to dispense with or modify. But supposing one of the tenders to be deemed satisfactory and be accepted: what means exist for the architect to adjust the amounts of the instalments to be paid on account? A mere lump sum for the whole gives him no guide in determining these. The same applies to the valuation and adjustment of such deviations, whether by way of addition or reduction, as may be ordered during the execution of the work. It is often provided that the amounts to be allowed for these are to be determined by the architect; but how? Without the possession of some better guide than the lump amount of the contract, all these matters must be mere guess work; and do we find in practice that either the public or the contractors are quite satisfied to abide by the guesses of the architect on these subjects? So far as my observation has gone, it appears to me that American architects generally do not command the confidence of either in this important part of their duty, and that consequently they are frequently displaced from the position they ought to occupy as sole umpires or arbiters between employers and contractors, and lose thereby both the emoluments and consideration which would attach to such a position.

The English system, in contrast with this, is as follows: During the preparation of or on the completion of the drawings and specification, the architect employs a building surveyor (one of a large, useful, and respectable profession), to "take out the quantities," as it is called, or in other words, to calculate with accuracy the amount of work of every kind required for the building. Should the architect be under any particular necessity for keeping within prescribed limits of expense, the surveyor often prices these himself, and advises the architect of the cost of any items that it may be desirable to modify or reduce, in preparing the specification. Ordinarily, however, this is not done till after the tenders are received. On the completion of the bills of quantities, they are lithographed, and a copy furnished to each party for whom a tender is to be received, whether they be invited by public or private advertisement. This, of course, relieves the contractors of nine-tenths of the trouble they have here, as, on receipt of the bills of quantities, they have only to append their prices and make up the amounts. As a consequence contractors can tender for ten buildings at less trouble to themselves than they can for one here, and the tenders are delivered with a promptitude and certainty that could not otherwise be attained. So fully is this system appreciated by the contractors as well as architects that it would be quite useless to ask for tenders in any of the great cities without quantities being supplied. Contractors would very properly tell architects, if called upon to come and estimate from his plans, that they had better use for their time, and that of their clerks, than to calculate quantities for him or his clients merely on speculation. It is not by any means, as has been suggested to me here, that British contractors are not so intelligent as those here, and do not know how to calculate quantities. Builders or building contractors there are as shrewd and intelligent as are to be found anywhere, but just because of this they are unwilling, each one, to waste his time doing what one could do for all; and, if a surveyor were not appointed by the architect, they would either refuse to tender, or meet and elect one to do the business for them. Their experience has shown them what might be expected; namely, that a skilled surveyor who makes a specialty of the business is more likely to analyze the drawings correctly than any one else, and that bills of quantities prepared in this way are more full and correct than any they could prepare for themselves, even if they could spare the time necessary to be given to it. Just as a man who is his own lawyer has a fool for his client, they would consider a man who insisted on taking out his own quantities was a fool for his pains. I have no doubt but that respectable American contractors generally would think the same if but they were given the alternative, and up to the present my experience has fully sustained that view.

When the tenders are received, should the amounts be excessive, the maker of the lowest is ordinarily invited to confer with the architect, and produce, for the information of the latter only, his detailed estimate, based on the quantities, which shows, of course, the cost of each item, as well as of the whole work. It is reasonably assumed that both the architect and contractor should be interested in having the work go on to a successful issue, instead of being abandoned as might happen on account of its extravagance, and accordingly there is neither jealousy nor mystery between the architect and contractor, as seems to prevail here. Usually the possession of the detailed estimate enables the cost to be adjusted to meet the wishes of the owner; the alterations necessary in the specification are made, and the work proceeds. It is the usual condition in the contract that the contractor is to deposit with the architect a copy of the detailed estimate, and that it is to be the basis for ascertaining the amounts due as instalments during the progress of the work, also for valuing extras or omissions. It is not usually shown to the clients, but the possession of it is of great service to the architect as giving him an insight into the manner in which the funds at his disposal are being expended, and placing him in a position to do strict justice between client and contractor, which he would not otherwise occupy. The detailed estimate is of equal service to the contractor, as it enables him to order his materials and make sub-contracts with great facility, and it is just as much a protection to every honest interest of his as of the client.

The cost of taking out the quantities (or in other words the surveyor's fee) is ordinarily defrayed by a commission which varies in England from one to two and one-half per cent., and which in inviting the tenders is arranged to be paid by the contractor who gets the work, who of course duly provides for it at the foot of his estimate. Of course it really comes upon the owner, as is proper, for who else should pay the whole expense of a building operation? But all experience has shown that it is no extra expense, but, like an architect's commission or an insurance premium, is money laid out to advantage. No building owner of any intelligence would be found to object to it. Should the work be abandoned it has been held by the courts that it becomes payable directly by the owner. In no case is it chargeable to the architect, whose commission of five per cent. is even more distinct from this item than it is from the salary of the clerk of works.

Although retained by the architect for the purposes above mentioned, it is not usual in England to make the contract refer to the quantities, but to the drawings and specification. It follows, therefore, that should there be any error by which the contractor suffers loss, the surveyor is personally liable to him. This element, about which sometimes a great noise is made in the English journals, practically amounts to very little. Experience has shown that such mistakes are rare, and that in general surveyors do the business more accurately than could the contractors themselves, and no really qualified expert, whether he be surveyor, architect, engineer, lawyer, or physician, should be afraid to assume the fair measure of responsibility which the practice of his profession involves.

In Scotland, however, a difference exists, which is characteristic of that canny nation, and is really though not apparently more economical. The contracts are usually taken there with special reference to the quantities, the contractor agreeing to supply the amounts of work therein stated, but with this proviso, that should less or more be required for the execution of the building as shown in the drawings, the difference is to be credited or charged, as the case may require. This to some extent lessens the surveyor's responsibility, but often involves a remeasurement of the work; but it secures that the client only pays exactly for the amount of work he gets, and the builder is sure of being paid for all the work he has done. It is liable, however, to the objection that the contract amount is not so definite and fixed as under the English system, and however it may find favor in Scotland, has as yet not been adopted south of the Tweed. Of course the main principles involved are identical, one being that the architect should have a controlling power in regard to the estimates and cost as well as every other particular relating to a building, and that these should be calculated in a regular and systematic manner.

I think a fair consideration of this system, whether as practised in England or Scotland, will show that it is just as well adapted to the practice of this country as of the United Kingdom, and that the position and influence of the architectural profession would be largely improved by its adoption. I am confident that the want of such a system has a good deal to do with the public dissatisfaction with the profession alluded to above. It clearly rests with the architects to take the first step in its introduction, unless indeed they choose to resign their proper position as the masters of the art of building. My experience has shown that the American public and building contractors are by no means slow to discern the advantage of any improved system of business, and I have found both quite ready to admit and recognize the utility of this. Some contractors, I have heard, object, but on a principle which will scarcely bear examination. They say on that system any one can tender and the competition will be too sharp. This is practically an admission of the efficiency of the system, and can hardly be entertained by architects, who, being employed by the owners, should consult their interests first. But more than one contractor who has objected to the system has acknowledged that he did so because it would be a safeguard to the owner. I have found, however, that there are plenty of honest and responsible contractors ready to admit its great utility, and to avail themselves of it also whenever it has been fairly offered to them. From the great cost of building operations here in comparison with the United Kingdom, a much less rate per cent. would pay for the service here than what prevails there—say one-half to one per cent.—and would in all probability save ten times its amount besides the other advantages referred to as likely to result from its adoption.

The supposed unwillingness of contractors generally to conform to the system has been put forward by some architects to me as an objection to it. This unwillingness, as above mentioned, I have not found to exist, unless in a few cases, and with a class of men least deserving of the attention of architects. Even if it did exist, are the contractors to be looked on as the proper persons to decide such a question, or does it not rather belong to the province of the architects?

I believe there are plenty of contractors who would do without architects altogether if they could, and as a parallel to their willingness to make their own calculations, we find this class ready on all occasions to prepare plans also, as they profess, free of charge. If the architects be disposed to abdicate their functions in favor of such contractors in deciding one question, they might just as well do the same with reference to the other, and become mere draughtsmen, under the direction of the contractors, at once. If the architects are afraid to get proper calculations made in the interest of and for the protection of their clients, merely because certain contractors do not like it, they might as well give up preparing accurate plans and specifications and the whole business of superintendence because the same class of contractors would much prefer doing without these things also.

Above all, the interests of the clients or building public imperatively demand that such an important branch of architectural business as the preparation of detailed estimates should not be neglected by the profession or handed over to those whose interests are adverse, and who, not being specially paid for them, can hardly be blamed if they keep their calculations for themselves, and try to recompense themselves in some other way.

The Scriptural question "Which of you intending to build a tower sitteth not down first and counteth the cost thereof?" must be answered negatively if we apply it to American architectural practice as it is; and if the result of beginning to build without being able to finish does not often take place, the almost equally unsatisfactory result of having to pay an enormous sum beyond what was originally contemplated happens too often, and, as in the case of the Governor's report already alluded to, brings no small discredit on the profession.

I trust that in instituting the foregoing comparison between British and American architectural practice, I have not overstepped the limits of fair criticism, my object being to place the experience of the profession in the old country at the service of those who practise the same in the new, and with a sincere desire and a sanguine hope that amidst all the progress making in other arts, the noble and important one of architecture may not remain behind, and that its professors may reap the benefit in being fully accorded the emoluments and consideration to which the practice of their art should so justly entitle them.

IRON AND THE SMITH.

From "The Builder."

Generally the discovery of iron is understood to have been long posterior to that of bronze. While it is as yet impossible to affix exact chronological dates to the first introduction of any of the elder metals into the service of man, it is ascertained, beyond reasonable doubt, that the employment of gold was earlier than that of bronze, and that the manufacture of bronze preceded that of iron. Silver is interposed (perhaps in the first instance by the poets) between gold and bronze; but of the justice of that attribution it is difficult to form an opinion. It is, however, easy to understand that metal which is found in a virgin state, as in the case of gold, would more readily yield its resources to human industry, than metal found only in a state of ore. But even here we must speak with some reserve, as we are aware of the actual existence, although rare, of tolerably pure virgin iron, in the form of meteoric deposit, while we are unable to cite an instance of virgin bronze.

But while we cannot reduce the date of the earliest work of the smith to historic time, there is no reason to doubt the sequence of the various metals, in so far as they were known to or used by man. It is rather the philosophical than the historical or chronological date which we thus attain; but that is ample for our present need. At a distance of time which is uncertain, but which is to be measured by millenniums, rather than by centuries, and which may differ widely in different regions of the earth, the earliest inhabitants of our planet who have left any indications of their affinity to ourselves carved rude implements of stone, horn, and bone. Almost as early as any marks of industry of this nature are the relics of a contemporary art. Man began to ornament, so far as we can tell, as soon as he began to work. With the lapse of time, the rude flakes of flint, or the hammers made of some hard stone, assumed greater elegance of form and delicacy of finish. During the period which has been termed the neolithic age of civilization, bronze first made its appearance. Late in the bronze period, and, comparatively speaking, late in the historic period, we are accustomed to place the discovery of iron, to locate it in Crete, and to attribute it to the Idæan Dactyli.

Pliny, in his Natural History, says, "Of all metals the veins of iron are most abundant." The metal is mentioned, under its Greek name *sideron*, by Thucydides, Euripides, and Æschylus, as well as by Xenophon. The earliest note of the word occurs in the Book of Genesis (iv. 22) where Tubal Cain is mentioned as the instructor of every artificer in brass (or rather bronze) and iron. The word here used, which is also translated iron where it occurs in the Book of Ezekiel, is *barzal*, which is derived from an Aramaic root meaning to pierce. Another word, *paldah*, cognate forms of which also occur in Arabic and in Syriac, is used by the prophet Nahum (ii. 4), and is explained by Gesenius to mean steel. It comes from a root meaning to cut. The Hebrew *barzal* appears as *parzat* in the Book of Daniel. It is difficult to identify either of these words with the Greek form, although that is originally allied to both the Latin *ferrum* and the English *iron*. We are, however, relieved from any doubt as to whether iron was known in the time of Moses, 3,400 years ago, by the discovery of a wedge or plate of iron embedded in the masonry of the Great Pyramid itself.

This instructive relic, like the half-fuzed magnifying lens found at Pompeii, throws much light on questions of early workmanship. It has been a great puzzle to those who attributed the first use of iron to a date not much more than 2,900 years back, how such sharp and well-defined hieroglyphics could have been cut, by the ancient Egyptians, on porphyry, granite, and the hardest stone. It may, indeed, be the case that, when bronze was the ordinary material for tools, the coppersmith had some secret as to the production of a very hard temper, now lost. But this is at best only a guess. From the certain proof that iron had been produced and wrought in the age of King Cheops, 5,400 years ago, we can better understand how the innumerable and exquisitely sunk symbols and figures were wrought on tombs, temples, and sarcophagi. And more than that, from the great similarity in the mode of treatment, that prevailed from the time of the Ptolemies back to the very earliest known Egyptian inscriptions, we have something closely approaching a proof of the use of iron as far back as the fifth Egyptian dynasty, if not in the time of Menes himself; that is to say, six thousand three hundred years ago.

From that earliest use—date it when we may—the art of the founder and of the smith has advanced, with enormous strides, to our own times. If we distinguish the manufacture from the fabrication of iron—that is to say, if we draw a line between metallurgy and smith's work—there may be some reason for the opinion that, while the former is still in a state of rapid progress, the latter has passed its zenith. We are not about absolutely to insist on this point. Of the truth of the former position there can be no doubt. We must explain what leads us to entertain a suspicion as to the latter.

The great mechanical characteristic of the present age is the substitution of steam power for manual labor. The signal for this enormous change—a change which, it is not too much to say, is tending entirely to revolutionize the relations of mankind to the world on which they dwell—was given by the genius of Watt. Our own eyes have witnessed, our own hands have labored at, step after step, the mighty transformation. We can remember when, on one occasion, on the completion of a locomotive engine by Mr. Stephenson, steam was got up, and the machine, though well up to its duty on the rails, was unable to propel itself over the floor of the factory. The inference thence drawn, and not unnaturally, by the first engineers of the day was, that it was pure loss of time to turn attention to the propulsion of steam engines on the common roads. This was hardly a third of a century ago, and what do we now see? At almost every county bridge, in some districts, at least of England, a notice is affixed that the arch will not bear the weight of a traction engine. Who has not seen these uncouth giants tracking their heavy and resistless course over the country, training behind them wagons and quaintly-shaped machines for scarifying and torturing the face of the earth, with apparent indifference to their number or their weight. Two very simple improvements have overcome the impossibility imagined by Mr. Stephenson. One of these is the old mechanical method of reduction of speed by cog-work. The piston travels at the speed which best suits the evaporative power of the boiler. The driving-wheel revolves at the slow pace fitted for progress over the road. This slow, irresistible progress is rendered possible by the great breadth of the wheels, and by the oblique grooving recently introduced on their circumference.

What has been done in the locomotive, from the express engines of Mr. Brunel, able to take a train over the low gradients of the Great Western Railway at the rate of seventy miles an hour, to the slow but mighty traction engines, and the self-moving agricultural engines of to-day, is going on in every department of the work of the smith and the fitter. Machines, not indeed endowed with intelligence, but unerring in their discharge of duty, and themselves the offspring of the noblest mechanical intelligence, now deal with iron almost as a swallow deals with mud. They forge, roll, hammer, plane, punch, and drill. They turn out hammered or pressed iron, untouched by the hammer of the smith, in every form; from the gun that weighs thirty-five tons to the hairspring of a watch. Hardly any tool can be named which is not produced, or likely to be produced, more readily, accurately, and cheaply, by machinery than by hand. But this great facility does not tend to improve the handiwork of the smith.

If we contrast this state of things with that which prevailed three hundred years ago, we shall see that against all our gain —and we are among the last to undervalue it—we have to set off a certain loss. The highest skill displayed in the work of the smith was found in the craft of the armorer. To that craft a fatal blow was given by the tilting-lance of De Montgomeri, when, in curious coincidence with the prophecy of Nostradamus, it entered the helmet of Henry II. of France. Three influences thus combined, and led, within a couple of generations, to the disuse of armor, and thus to the extinction of the most skilful, workmanlike, and artistic employment of the smith. These were the death of the King of France, which was too serious a matter to result without producing a powerful effect from the amusement of the tourney; the increasing excellence of gunpowder and guns, and the reign of a female Sovereign in England. When we look at the armor of the time; when we note that the tilting armor, which, by the introduction of the pauldron and other devices, had lost its symmetry, attained the weight of a hundred pounds avoirdupois; when we observe the exquisite delicacy with which the Milanese armorers wrought the mail that was like steel gossamer, or the scale or folding plate that fitted the limbs like the carapace of a lobster—we may well be of opinion that few smiths of the nineteenth century can hold a candle to their ancestors of the sixteenth.

Connected with the extreme care that was given to the fabrication of defensive amor, was that bestowed upon offensive weapons. The fame of two descriptions of sword-blades has been established since the Middle Ages, and even since the crusades. One of these is the Toledo rapier, a long, straight sword, the undoubted excellence of which must, we believe, be chiefly attributed to the original quality of the ore employed by the makers. The other was the Damascus sabre, or scimitar, a curved blade, of such exquisite temper that, when handled by a master of that description of fence, it could cut in two with equal ease a floating scarf of gauze or silk, or the neck of a horse, or of his rider. The excellence of the Damascus blades we are disposed to attribute rather to the skill and patience of the smith, or at least of the maker of the iron, than to the original quality of the metal. For it is to the repeated working up of scraps, and rusty scraps, of iron that the beautiful mottling of the Damascus blades is due. It seems to us not improbable that these numerous welds, none of which are so perfect as to have been obliterated under the hammer, act like the teeth of a very fine saw, and thus cut with a keenness unattainable by a more homogeneous and smoother edge. It should, however, be borne in mind that the difference between the iron produced from different ores is, in our present stage of metallurgic practice, extreme. There is an iron made in our North Midland counties which is so hard that it is almost impossible to break up old castings made of it. On the other hand, when the French *usines* began to make rails, some twenty-one years ago, an English fitter, with a cold-chisel and a hammer, could cut one of them in two in less than a quarter of an hour.

The earliest use of iron as an offensive weapon was probably in the form of arrow-head. Bright points of this nature, which are said to be a thousand years old, are preserved with great reverence in the museums of that wonderful country, Japan. It is far from improbable that meteoric iron was, in the first instance, thus employed. At all events, the purity of the metal, and the care and patience with which it was wrought, were extreme. Among the antiquities of India is to be found an iron column so large and so perfect that we could not produce the like at the present time without the aid of steam machinery.

After the demand for the highest class of smith's work—that is to say, armor and offensive weapons intended to pierce armor—had ceased, the decorative taste of Italy, of Germany, and even of our own country, was gratified by the production of much admirable ornamental iron work. Park and garden gates tasked the skill and displayed the taste of the smith. The uniformity of a line of iron palisades was agreeably broken by flourishes and scrolls, each of which was stamped by a certain individuality. In the South Kensington Museum are to be found fine specimens of English and Roman work of this nature. Much ironwork is now in rapid decay throughout the country, which it would be a good deed to rescue from destruction. We saw a beautiful specimen of this kind, not so very long ago, on a *perron* in the High street of Rochester. In other places the intelligent care of the proprietors, and the renewal of painting and of gilding, has kept the ironwork of the seventeenth century as fresh as that of to-day. Such are the goodly scrolls and flourishes that adorn the Town Hall of Guilford, and decorate its great projecting clock, erected in 1681.

To the demand for this bold, permanent, and manly kind of ornamentation a fatal blow was given by the increasing skill of the moulder and of the caster. The heavy railings recently removed from the west end of St. Paul's Churchyard were among the first, if not the very first, in which cast was substituted for wrought iron. It is said that the enterprising contractor made much money by his ingenuity in this respect. Economy soon prescribed laws of retrenchment as to ornamental ironwork; and here again, as in the case of the invention of gunpowder, the increased use of iron was made at the expense of the occupation of the smith.

The points to which attention are now chiefly directed, with regard to iron, apart from the mischievous result of ill-regulated competition in producing, for the smallest price, the largest possible quantity of inferior metal, are its reduction from the ore without the intervention of manual labor; the chemical purification of the metal, and the removal of those minute proportions of sulphur and of phosphorus which destroy its tenacity; and the production of steel or carbonized iron by simple procedures. There is, perhaps, no instance in which mechanical invention is removing a greater curse from labor than in the case of puddling iron. Those who have watched the process, or who have studied the beautiful representations of furnace-work given by the graceful pencil of Moritz Retsch, in his illustrations to Schiller's "Song of the Bell," are aware of the exhausting nature of the labor undergone by the puddler. It is, we think, the hardest labor now performed by man. As involving a certain amount of experienced judgment, it is of a higher grade than that of the brick-moulder; but the suffering it involves from heat is far keener than that inflicted, in the latter case, by cold and damp. For dirt they are about on a par. It is always the case that those occupations which, from their danger or their hardship, command extra wages, have a demoralizing effect on the workman. At the same time, just in proportion to the danger, especially if there be any risk of life, is it found that any attempt at introducing an easier process is steadily and fiercely opposed by those who think that they have acquired a vested interest in their craft. The manufacturers of iron are, to a great extent, at the mercy of the puddlers; and the chief gainers by the high wages which this arduous work rightfully earns are, no doubt, the brewers. It is, therefore, in the interests of morality, of public health, and of the elevation of the workman in the social scale, no less than in that of the manufacturer and of the purchaser of iron, a source of great satisfaction to find that the experiments recently made on the mechanical puddling of iron have been so satisfactory, that it seems now to be only a question of time as to the entire disuse of the hand-puddling process.

Anything which tends to make manufactured iron at once cheaper and better is a boon to the smith. It is the bad quality of common iron, rather than any inherent defect in the metal, which renders the architect often averse to the employment of smith's work, when nothing else is so truly appropriate. We must conclude that what renders one sample of iron less tenacious than another is some chemical impurity in the metal, which it is within the power of perfectly instructed metallurgical skill to remove. These admixtures are often extremely small, if measured by any test but that of the depreciation of the quality of the iron. Measured by that test, their presence assumes extreme importance. Mr. Kircaldy, by his numerous experiments, has added no small amount of positive knowledge to that which we possessed before on the actual resistance of various makes of iron, both to tension and to compression. In his "Experiments on Wrought Iron and Steel," we find the breaking-weights of iron bars to range from 160,520 pounds per square inch of fractured area in the Swedish R. F. charcoal iron, to 63,883 pounds per square inch of fractured area in Russian C. C. H. D. iron, a difference not far short of three to one. In iron plates, looking at domestic production only, the breaking-weight per square inch of fractured area ranges from 92,468 pounds in Yorkshire plate to 43,460 in common Scotch ship-plate. This is more than two to one in favor of the Yorkshire iron. It is also a very suggestive comparison with reference to naval security.

An uncomfortable suspicion pervades the public mind—and even professional men are not altogether free from its influence — that, under some unexplained circumstances, the texture, or molecular arrangement of iron used in buildings or in machinery, undergoes a mysterious change. Fractures of axles or of tyres in railway collisions are the phenomena which have been chiefly cited as requiring this very alarming explanation. Many writers have ridiculed the idea; but ridicule is an unsatisfactory substitute for scientific analysis. It has, however, been pointed out that "the two different appearances, respectively known by the terms 'a fibrous fracture' and a 'crystalline fracture,' are produced by the iron breaking gradually in the one case, and suddenly in the other. Hence, when the appearance presented was fibrous, it only proved that the piece had been torn asunder; when it was crystalline, that it had snapped." This view, which is not a matter of theory, but the outcome of experiment, fully explains all the phenomena of fracture which have led to the idea of some unexplained structural change. It is of the first importance, to the architect as well as to the engineer, that the facts should be known. An unexplained, mysterious danger, such as would be that of such a molecular change, if it could possibly occur without ascertainable cause, is more to be dreaded than any of those casualties which it is within the power of competent science, backed by competent care, almost absolutely to preclude.

By immersing specimens of iron in dilute hydrochloric or muriatic acid, the foreign impurities are removed, and the texture of the metallic portion is exposed to examination. Long immersion in water—or at least in *some* water—has the same effect, as we have witnessed, in the bolts of a sunken vessel that had been for some fifty years exposed to the alternate action of fresh and salt water in the river Seine. Thus treated, puddled iron, rolled or wrought iron in its lowest state, as in Scotch and Welsh puddled bars, presents a woolly appearance. In iron of a superior quality the appearance presented is that of very fine threads or hairs, lying closely together. This is remarkable in Farnley or Bowling iron, as also in Russian bar. Swedish tilted bars present, even to the naked eye, a beautiful silvery variegated appearance. Of the beautiful Styrian iron, which is so highly prized in Italy, and which was probably employed by the famous armorers of Milan, we regret that we have found no analysis or definite scientific description. It is most evident—to use a mode of expression that has recently come into favor—that there is iron and iron, no less than that there are smiths, and that there have been smiths.

LONG RAILWAY RUNS.

From "The Engineer."

It is a well understood proposition, and one generally accepted as true, that nothing operates more effectually to increase the time spent in accomplishing a given journey by rail than working trains on the short-run system; and it is also true that so-called fast trains which stop frequently are the most expensive that it is possible to use. The reason for this last fact is obvious. Not only is much fuel wasted in doing work which is afterwards undone by the brakes in a way which we have already fully explained when dealing with the rolling stock of the Metropolitan Railway, but the speed of the train when running must of necessity be very high in order that the train may, in any sense, fulfil the condition of being "fast." But high speeds represent a great consumption of fuel, and augmented wear and tear of engines, carriages, and road; and it will be found, as a result, that very few fast stopping trains are run by railway companies who understand in what true economy consists. Trains which stop at many stations in close proximity are essentially slow, no attempt being made to travel at a high velocity between the stations; and those who require conveyance over long distances select trains the average velocity of which, measured by the mile, is not very high—continuous running without a break getting the train over the ground in excellent time. As an example of the latter class of train we may take the Scotch mail on the Great Northern. This train accomplishes the whole distance between London and Edinburgh—about 400 miles—in nine hours and thirty minutes, the average speed being about forty-two miles an hour. It would be necessary to run this train at an enormously higher velocity if the stops were more numerous. As it is, we believe we are correct in stating that on no other line in the kingdom is a train to be found which gets over a greater distance in nine and a-half hours. It is true that on the Great Western trains are run which accomplish 200 miles in about four hours and twenty minutes; but a run of 400 miles is not made on any line, save the Great Northern, in much less than ten hours. Long runs require very good engines and excellent rolling stock; but these being given, long runs are decidedly conducive to economy, and there is no reason why they should not be more freely adopted than is now the case on many important lines, and on all such lines the principle apparently might be extended with advantage. For example, there is apparently no good reason why the run from London to Liverpool, *via* Runcorn, should not be accomplished without a stop, or at all events with but one stop, and in say four hours, the distance being, as nearly as may be, 200 miles. The road could not easily be made much better than it is, but the existing carriages would, for obvious reasons connected with the comfort of the public, not be suitable for such runs, and something in the nature of Pullman cars would be essential; at all events, free circulation through the train would be required. But this presents no difficulty. It is perhaps open to doubt whether a locomotive could be constructed which might be relied on to accomplish a journey of 200 miles in four hours without stopping, and the work would no doubt be exhausting to both driver and stoker. We have already expressed our opinion concerning the locomotives required for such work in a former impression, and we shall not further refer to the matter now, except to say that we believe it to be quite possible to construct engines which would be perfectly reliable, although they would, in some important matters of detail, differ from ordinary locomotives. The great difficulty to be contended with in working trains on such a long run as that under consideration lies in providing water enough. This would not stand in the way of the London and North-Western Company, who may use Ramsbottom's tanks, of which they have at present the monopoly. But it would be otherwise with the remaining English companies, who, precluded from using Ramsbottom's system, would be compelled to resort either to the use of tenders of unprecedented dimensions, or to some other device for filling up their tanks. There are grave objections to the use of large tenders, which would probably neutralize all the advantage to be gained from long continuous runs, but it is by no means certain that Ramsbottom's is the only arrangement by which a tender while in rapid motion can be replenished with water.

The idea of working trains between London and Liverpool direct resulted in nothing, although at one time it was stated, with some show of authority, that the directors were actually providing the requisite rolling stock, and on the Midland Railway trains no longer run without a stop to Leicester—a fact in some measure accounted for by the difficulty met with in providing water without the aid of the Ramsbottom trough. It may, from these circumstances, be argued that the long-run system is already fully developed; but this we dispute. We have very little doubt that, on the contrary, as great towns such as Liverpool increase in size, it will become almost essential to establish a railway service between them and the metropolis so rapid and so heavy that it can only be dealt with by trains running directly from city to city without a stop. If, for example, Liverpool can provide a sufficient number of passengers to London at any given hour in the twenty-four to fairly fil a train of say twelve coaches, it will be worth while to run that train through to London without a stop; and we feel certain that, if such a through train, properly constructed, were put on to-morrow, making the run say in four and a-half hours, it would not only be the most popular train on the road, but also the train worked most economically. However opinions may differ in this country as to the value of the long-run system, it is certain that our friends in the United States are determined to give the system a fair trial. Since the 1st of June the Pennsylvania Railroad Company have commenced working long-run trains between Pittsburgh, Philadelphia, and New York. The distance is 444 miles, and the train stops on the road but three times: at Altoona for five minutes, after a continuous run of 117 miles from Pittsburgh; then comes a run of 132 miles to Harrisburg, where the train stops for twenty minutes for dinner; the next stage is to Philadelphia, 105 miles. The train stops here for five minutes, and then proceeds across New Jersey for 90 miles to New York. Nothing at all comparable to this work has ever before been done on a railway except once or twice by special trains under exceptional circumstances. The run of 132 miles is no doubt a wonderful feat, and redounds not a little to the credit of American engineers. The entire line, we may state, is laid with 60-lb. steel rails, laid on oak sleepers and thoroughly well fished, the track being admirably ballasted. The train is made up of Pullman cars of the most luxurious description, and fitted throughout with the Westinghouse brake; the engines are supplied with water when running on Ramsbottom's system, and no pains appear to have been spared by the company to provide for the safety and comfort of the public.

As regards the velocity of this train, we learn from the published time-table that the train leaves Pittsburgh at 7.25 A.M. and reaches New York at 9.30 P.M. Deducting half an hour for stopping, we have as the total running time 14 hours 5 minutes, or say an average velocity of 31.7 miles an hour. Not a high speed certainly, but in no other part of the world is it easy, we believe, to accomplish a distance so great in the given number of hours. The first run of 117 miles is performed in four hours, or at the rate of 29.25 miles an hour; the next run of 132 miles is done in four hours, or at the rate of 33 miles an hour; the distance from Harrisburg to Philadelphia, 105 miles, is run in three hours fifteen minutes, or at the rate of say 32.3 miles per hour; the final 90 miles across New Jersey being accomplished in two hours and fifty minutes, or about 32.1 miles an hour. We take it for granted that no great difficulty would be encountered in running the train at a higher speed, and performing the whole distance say in ten hours instead of fourteen if it were worth while. As the facts stand, however, they prove that in America work is being done which deserves to be imitated in the old country, and its importance in a new and thinly populated country like the United States cannot easily be overestimated. We have no doubt that the possibility of running a locomotive continually and regularly for a distance of 132 miles will only give an additional stimulus to our American friends; and so, if we do not mind what we are about, we shall have some enterprising Yankee coming among us and bringing with him his own engines and cars, and running regularly from London to Liverpool in four hours, while we are debating whether it is possible to design an engine which can run for four hours without stopping and without a breakdown. Not the least remarkable feature in the working of the train to which we have referred is the circumstance that the engines make continuous runs of four hours without heating or getting the tubes so choked up that they cannot keep steam. We commend the facts to the attention of our railway men.

NOTES ON THE SUBSTITUTION OF STEEL RAILS FOR THOSE OF IRON IN THE CONSTRUCTION OF RAILWAYS.

BY M. DESPRET

(*Read before the Brussels section of the Association of Engineers.*)

From "The Review of Mining."

THE writer of this paper proposes to answer the two following questions:

First.—*Under what circumstances is it advantageous to make use of steel rails instead of those of iron?*

Second.—*In what manner should steel rails be employed?*

In order to answer the first question, M. Despret is of opinion that several matters should be taken into account.

In the first place, the causes which influence the durability of iron rails.

Next, the cost of periodically relaying the rails.

Next, security in the passage of the trains.

And lastly, the modifications which may eventually be introduced into the form of rail now in use.

M. Despret commences by passing under review the causes which influence the durability of rails. These causes may be classed under two heads: those which are inherent in the rail itself, and depend on its quality and the material it is composed of; and those which, although unconnected with the rail itself, depend on the action of the wheel-tyres upon the rail.

As regards their material, rails may be made of either iron or steel, but the latter offer a much greater resistance than those of iron to the strain caused by the passing of the trains. This superiority consists not only in their chemical, but also in their physical composition—steel rails being perfectly homogeneous, while those of iron are composed of different layers imperfectly welded together.

With respect to their quality, steel rails give greater guarantee of stability than those of iron; the quality of the latter being excessively variable, while that of the former is much more uniform.

The steel rail should, then, endure far longer than the iron rail. Opinions are, however, much divided as to the relative durability of the two, some engineers maintaining that the steel rails will last only twice as long as those of iron, while others assert that ten times is the correct proportion.

M. Despret brings to this subject the result of experiments which he has made on a portion of permanent way with a gradient of 18 to 20 millimetres per metre (1 in 50 to 1 in 55.) Iron rails of excellent quality, laid on this gradient, have lasted three years, with a wear of 10 millimetres (0.393 inch); while steel rails, which were laid on the same gradient four years ago, have undergone, after these four years of service, a wear of only 4 mil. (0.1572 inch), the table preserving, at the same time, a perfectly regular form. If these steel rails continue to wear in only the same proportion, they will last three times as long as those of iron.

M. Despret remarks, that in comparing the relative durability of steel and iron rails, account should be taken of any improvements which may be introduced into the manufacture of iron rails. Among these improvements, he especially mentions that which would result from the use of the Danks furnace for puddling, thus allowing of the manufacture of iron rails, the homogeneity of which would approach that of steel rails.

Passing on to the action of the tyres on the rails, M. Despret remarks that this action is more or less intense, and that its intensity depends—

Upon the traffic;
Upon the load on the wheels;
Upon the speed of the trains;
Upon the section of the line;
Upon the laying of the permanent way;
And lastly, upon the state of maintenance of the tyres.

M. Despret analyzes the action on the durability of the rails of each one of these causes, dwelling especially on those which exert the greatest influence on this durability.

The wear of rails is in proportion to the traffic—that is to say, to the number of trains passing over the line. It would be very interesting to know how many trains could pass over a rail before it became unfit for service, while taking into account any other circumstance, independent of the traffic, which might influence the durability of this rail. Experiments made by the Lyons Railway Company have furnished these data, in the case of iron rails laid down where exterior causes of deterioration can only exercise a secondary influence. The result of these experiments is, that an iron rail of good quality, laid under these conditions, can endure, before being rendered unfit for use, the passing of 5,000 trains; that is to say, for a traffic of 8,500 trains per annum, on a line of way—which corresponds very nearly to 23 trains a day—the rails of this way, if rolled of iron of good quality, should last 10 years.

The load on the wheels exerts a more or less destructive action on the rails, in direct proportion to the amount of this load.

M. Despret, remarking that under ordinary conditions, a mean load of 12 to 13 tons per axle was usually admitted, gave it as his opinion, that on account of the insufficient stabiliiy of the permanent way, it is advisable not to increase this load on a single pair of wheels, and especially not to reduce the wheel base.

The section of the line has great influence on the durability of the rails. When the gradients are sufficiently steep for the force of gravitation to exceed the inertia of the trains, it becomes necessary, in order to moderate their speed in descending gradients, to bring the brakes to bear, which cause considerable deterioration to the rails.

The rails laid on curves also suffer damage to a greater extent than those laid on straight portions, and their deterioration from this cause is greater as the radius of the curves is less.

On certain portions of the line, independently of all other equal conditions of wear, the rails are subjected to exceptional strain; these portions are near stations, at stations themselves, where frequent shunting takes place—in fact, wherever it is necessary to apply the brakes frequently.

After thus analyzing the causes which influence the durability of rails, M. Despret points out the effect which they produce. Those causes which are not inherent in the rail itself produce more important deteriorations in proportion as a greater number of them act at the same time, and also as the action of each of them is more intense. Though these causes seldom act all together, they never act singly, and the effect which they produce upon the rails will be greater or less according to the degree of intensity of the causes which operate at the same time. On the other hand, these effects will be different according as the rails are of iron or steel, and also in proportion to their quality.

The second subject to be considered, in order to solve the first question, is the expense resulting from the periodical renewing of the rails.

This expense is represented by the difference in value between the new and the worn-out rails in addition to the labor required for relaying. In order to compare the expense due to the periodical renewing of the iron rails with that of the steel rails, the durability of each, and also the interest on capital expended in their purchase, must be taken into account. A table might therefore be prepared, showing the expense per annum incurred by the renewal of the line with iron as against steel rails, corresponding to the different periods of the duration of each.

It appears from a table prepared with this object, that, in order to preserve the same annual expense, the steel rails should last at least twice as long as those of iron.

A third subject which should be taken into account is security to the traffic. In connection with this point, M. Despret remarks, that in certain portions of the line, accidents which are due to the rails are always of a serious character, as for instance, in tunnels, on high embankments, and on viaducts. In these portions of the line nothing should be neglected to ensure the stability of the permanent way, including the use of rails which afford the greatest safeguard.

Lastly, account should be taken of the modifications which may be eventually introduced into the form of rail at present in use.

With reference to this subject, M. Despret calls to mind the numerous experiments that are made to improve the permanent way. Among the systems tried, there are some in which the present form of the rail is completely altered. Even if the present section be retained, the question may reasonably be asked, whether it will not ultimately become necessary to increase the area of the section, in order to present a greater resistance to the load that may be brought to bear upon it.

In prospect, therefore, of future modifications, the present section of the rail must not be calculated for a too long duration. In fact, inasmuch as the use of steel rails only becomes economical under the condition that they last at least twice as long as those of iron, it might happen that the steel rails would have to be taken up before they had rendered all the service that might be expected of them to make their use economical.

What period, then, would it be advisable to set to their duration? M. Despret is of opinion that it should not exceed twenty years.

After having passed in review the different matters which it is necessary to take into account in order to answer his first question, M. Despret gives the answer in the following terms:

In the first place, steel rails should be universally employed where the safety of the train is at stake; as in tunnels, on viaducts, or on high embankments. Steel rails should also be employed on all portions of the line where iron rails can only be expected to last ten years, that is to say—

In all lines where there is a greater traffic than 8,500 trains per annum.

In all gradients greater than 10 millimetres per metre (1 in 100), descending in the direction the trains run.

In curves the radius of which is less than 500 metres (nearly 25 chains).

In the proximity of stations, where the speed of trains must be slackened.

In stations, and in those portions of the way where shunting takes place, or where the brakes are frequently applied.

In order to enable the import of these conclusions to be realized more readily, M. Despret applies them to the Luxembourg line.

When this railway had only a single line of way, there was reason to make use of steel rails over its whole extent, because more than 8,500 trains passed yearly over this single line of way.

When the way was made double, however, the conditions as to the use of steel rails were altered. As the number of trains on each pair of rails became only half what it was before, the traffic was not such as would justify the employment of steel rails; but other circumstances, under which their use was warranted, might be taken into consideration, and especially the inclination of the gradients. Thus, in the portion of the line traversed by trains going from Brussels to Arlon, steel rails should be laid on all gradients steeper than 10 millimetres per metre (1 in 100), descending towards Arlon, and, inversely, on all portions of the up line of the same descending gradient traversed by the trains going from Arlon towards Brussels.

M. Despret next takes into consideration his second question, which is in the following terms:

How should steel rails be employed?

Up to the present time, the managers of railways who have made use of steel rails, have confined themselves to the change of substance and not of form of their rails.

A French company, that of the Northern Railway, have looked at the matter in a different light. Starting from this fact, that steel rails are much stronger than those of iron, this company has adopted a steel rail instead of one of iron, but has reduced the section from 37 kil. (81½ lbs.) to 30 kil. (66 lbs.) per lineal metre (1.093 yard).

M. Despret read several passages from a report published by the Northern Company, in support of the system which it has adopted. After enumerating the advantages possessed by steel rails over those of iron, the report says:

"The advantage of the substitution of steel rails for those of iron is then evident, if the first cost be not considered an objection; now, in actual practice, by taking advantage of the difference in the strength of the two materials, the rails may be reduced to 30 kil. per lineal metre, still leaving them of superior strength to the iron rails which they replace. By these means, not only will the excess of first cost be reduced, but also the cost of laying will be much more economical than those of iron rails."

M. Despret differs with the report as regards the saving consequent on the adoption of the steel rail of 30 kil., inasmuch as the result at which the Northern Company has arrived is founded on a difference of only 70 fr. (£2 16s.) per ton for the steel rails, whereas the difference, at least in Belgium, is much greater.

However that may be, by applying the prices current in Belgium to the laying of a line with steel rails of 30 kil., as against iron rails of 37 kil., M. Despret finds the cost of the way with the former rails is not much greater than the construction with iron rails of 37 kil.

In the adoption of steel rails, then, there is a choice between two modes of action; in the one the section of the old iron rail is preserved in the new steel rail, and in the other this section is reduced.

To the question, Which of these two systems should be followed? M. Despret declares himself at a loss to give a decided answer.

If the iron rail of 37 kil., in general use at the present day, was found to be of insufficient strength, there would be no hesitation in taking advantage of the increased strength of the steel, by giving to the rails manufactured from this metal the same section as the iron rails of 37 kil.

Now, the question is, whether this iron rail of 37 kil. is of insufficient strength or not.

With regard to this subject, M. Despret recalls a very interesting discussion which took place in 1864, at a meeting of the Societe des Ingenieurs Civils de France, on the occasion of the publication of a treatise by M. Eugene Flachat, on the wear and the relaying of rails.

In this treatise, M. Flachat maintained that the iron rails of 37 kil. were found to be of insufficient strength, and that it had become necessary to increase their section. All the engineers of the great French companies took part in the discussion, and they all declared that, in their opinion, the iron rail of 37 kil. was sufficiently strong, provided that it was of good quality.

But M. Despret remarks that the conditions of the traffic are not the same as they were ten years ago. Heavy engines, with a large number of axles and short wheel base, which cause considerable strain to the permanent way, were in 1864 only the exception; now their use is becoming day by day more extended, and it may even be reasonably asked whether the power of these engines will not be still further increased, so as to increase at the same time the load on the wheels.

Under these circumstances, there is great reason to fear that the iron rail of 37 kil. will not be sufficiently strong, and therefore there may well be hesitation in adopting a reduced section for the steel rail.

Notwithstanding this, M. Despret considers that the Northern Company have reason for the decision arrived at by them. On a system like that of this company, there is not the same strain on all portions of the line; and by adopting the steel rail of 30 kil., the Northern Company can immediately work up again the steel rails on those portions of their way liable to the greatest strains, without incurring any very great loss. If, in future, these rails of 30 kil. should be found of insufficient strength, they can be replaced by those of greater section, and still utilized on the portions of the line where the traffic is lighter.

M. Despret remarks, in conclusion, that the results of his investigation lead him to consider, that although the question of the substitution of steel rails for those of iron may now be settled in principle, it is far from being settled in all its details, and that because a sufficient amount of experience, which requires a lapse of time, has not yet been acquired to determine precisely all the conditions respecting the employment of steel rails.

FRENCH ENGINEERING IN THE EAST.

From "The Building News."

Nearly thirty years ago a number of French engineers persuaded the ruling prince of Egypt that he might bestow inestimable benefits upon the country, besides creating for himself an imperishable renown, by undertaking to construct a barrage, or dyke of prodigious dimensions, in combination with a system of canals, which should reclaim from sand and salt marsh the richest of the Egyptian lands that had lain uncultivated for centuries. The history of this project, now that it has been illustrated by the recent inundations, and now that, according to the last authentic intelligence, it has come to a close, through the works having proved useless in a double sense, is worth remembering. They were intended to provide water where there was none, and to regulate its overflow when there was too much; and they accomplished neither purpose. The able but imperious Pasha Mohammed Ali, infatuated by some professional men from Paris, conceived the idea of superseding all natural and traditional provisions or artifices for the irrigation of the soil by erecting a stupendous dam, connected with a labyrinth of channels, which should at once restrain and distribute the annual flood. To this end he almost stopped the navigation, paraded his plans on Parisian maps, set an array of half-starved peasants to labor upon mounds of earth and aqueducts of masonry, and expended upon engines and engineers, both French, an incalculable amount of money. The promoters took a pride in attributing so grand a scheme to the First Napoleon; but a quarter of a century after the barrage of Mohammed Ali was begun, it was in the same condition as another, constructed six hundred years before, which the Nile, at its first extraordinary rise, overthrew. It is well known that the Nile, approaching the sea, divides into two branches—the Damietta and the Rosetta. It was here that the projectors thought to store up the waters which had come down from the upper regions, by throwing dams across both channels; yet, after an incredible waste of toil and treasure, their work remains a ruin, never to be repaired. No doubt its originators had an amount of reason in their hope, which was, however, too daring for fulfilment through any means at their command, though a generation which has witnessed the completion of the Mont Cenis tunnel and the Suez canal might possibly not shrink from reviving this ambitious scheme were it founded on a more practical basis. For, as it has been plainly described by the French engineers, the object was to hold up the waters of the Nile, during the eight months of ebb, so as to maintain them at the level of the soil and supply Lower Egypt during that period with the same amount of water as the period of the yearly inundation, it being estimated that the enormous expense of the work itself and the new system of canalization it would necessitate would be more than compensated for by a vast increase of cultivable land in the Delta, or space between the two arms of the Nile, and the setting free of innumerable hands from raising water for purposes of tillage. The conception was worthy, perhaps, of old Egypt; unhappily, the attempt at its execution, since the first stone was laid by Mohammed Ali in 1847, has been incommensurate. The foundations of a double bridge were raised, spanning the ample stream, with its deep, soft, muddy, and changeable bed—an experiment such as that of damming the Thames at Greenwich, with a full tide running and no bottom to hold by. The engineers got on famously at first; they threw up a series of light and lofty arches; they created an imposing architectural facade, turreted with admirable effect above each of the sluice-gates, and towered in the centre and at the corners. Nothing could be more majestic than the general aspect of the barrage as it promised to approach completion, and nothing more apparently practical than the apparatus of sluices, with their double cones of hollow iron, working, as Dr. Russell says, on radii of rods fixed to a central axis on each side of the gate. These cones increased in dimensions from the bottom to the top, the lower filling with water as they descended into their beds of masonry. It was never proposed to keep them shut all at one time, because the pressure of the Nile, rolling from its remote fountains, would in that case have probably swept the entire elaboration away; but even then it was found that these ramparts raised against nature vainly struggled with it. The locks, with their terraced quays, speedily exhibited signs of dislodgment from their sites; the archways burst; the canal-ways were gorged; the neighboring dams of earth availed nothing; and what is left of the barrage at this day attests a colossal scientific failure, the results, such as they continue to be, proving mischievous rather than beneficent to the country, not one shilling having been returned to the Viceregal treasury of the millions upon millions sterling that were sunk. It was so formerly in India, where a French engineer was not less essential at every native court than a French colonel of cavalry. This is said without disparaging in the slightest degree the science of France; it points rather to the pseudo-science of adventurers, half political and half financial—for nothing could be more absurd than any depreciation of foreign engineers in these respects. A peculiar genius, however, belongs to every nation, consequent, in a great measure upon the necessities which create habits. Thus neither the English nor the French have any monuments to display equal, or even similar, to the sea-dykes of West Cappel, the Helder, and the Isle of Walcheren, in Holland; they do not require them, though the requirements of coast-railways are often formidable enough. And yet the great dam of the river Fureus, St. Etienne, France, is a trophy of enterprise and skill, though not upon any gigantic scale; it secures an immense body of water in permanent reservoirs; it guards against all danger of overflow; it has needed scarcely any reparation during the last twelve years; and it has withstood the shock of a waterspout historically calamitous. There is a barrage too, in Spain, fifty yards high, and two hundred years old, but curvilinear in form, whereas all the French barrages are straight; but both differ in many essential particulars from the Egyptian, in which more masonry is employed, more sluices are capable of being opened, and an artificial foundation was sought, though never found. The engineers at Fureus had a rock to build upon; those of the Nilotic Delta never found their way, properly speaking, through the quicksands or the mud. Little wonder, then, that the last vestiges of their labors are vanishing. Mr. Aymard, in his book on Irrigation in Spain, gives a history of the barrage at Puentes, which cost an astonishing sum, and which gave way at the base in 1802, the architect having conceived the notion of founding it upon piles in an alluvial soil, instead of going down to the solid rock at any sacrifice. Remarks of a similar kind have been applied by the highest authorities to most of the dykes of this complex kind, composed of bridge, dam, and tunnel at once, in Europe, and they apply with tenfold force to the magnificent "Folly" of Mohammed Ali and his Parisian engineers in Egypt. As a last resource, the reigning Viceroy and his predecessor thought it practicable to recover from the ruins of the French barrage some aids towards the construction of a new one by English engineers; but the advice given them, and to the former, especially since the late disastrous inundations, has been to get rid of the obstruction altogether. Nothing less than the dimensions and solidity of a breakwater would curb, in redundant seasons, the fall and flow of the Nile, carrying with it, as it does, the impetus of thousands of miles, gathered from elevated sources, and only moderately diminished in its progress through the lakes and down the endless valley.

Even in constructing the Suez Canal, the French engineers discovered many difficulties and perils upon which they had not originally calculated, and peculiarly so in the case of the necessary embankments; but what was the scientifically-arranged meeting of two seas in comparison with the perpetual downpour of a river so fluctuating, and yet so voluminous and incessant as the Nile? It was not as a protection against the waves and winds of the Mediterranean alone that the Cyclopian breakwater of Alexandria was designed, but also against the turmoil of the waters caused by the irregular rushing of the great Egyptian stream. As an illustration of the meaning implied, reference may be made to some vast works undertaken, not long ago, on the Danube. In the recommendatory report, it was suggested that the current should be, in some measure, controlled; but the ultimate decision was to smooth the bed, to set the water free by all possible expedients, to deepen and straighten instead of curbing or diverting; and this is the lesson which, after the life of a generation, has been learned in Egypt. The barrage of the Nile, with all its complications of dykes, viaducts, sluice gates, tunnels, canals, and pumps, was far from being pronounced complete when it became a ruin, and a ruin it will remain until the last traces of M. Linant's ill-judged undertaking have been either swept away by other floods or overwhelmed by the sands. It is, and was from the commencement, to be feared that the work was urged upon the successive rulers of Egypt from political motives rather than from any real belief in its feasibility; but the reminiscence is an unpleasant one of the extorted toil, no less than of the extorted taxes, wrung from a poor and helpless population to aid in this realization of a dream indulged in by a Franco-Egyptian Society which once actually proposed the drainage of the Lake Mœris, as though Egypt were Holland, unduly invaded by the billows. Of course a philanthropic incentive may have prompted some among the engineers who pressed their services upon the Pasha Mohammed Ali and his equally credulous successors. It would have been a great advantage, no doubt, if the immense amount of manual labor now devoted to raising driblets of water from the river by rude appliances of primeval fashion, which have exhibited no improvement for centuries past, could have been saved, and this, indeed, was among the objects proposed to be fulfilled by M. Linant's unfortunate barrage: but the same end could have been obtained, at a hundredth of the cost, by another process, as was demonstrated at the very time when these leviathan plans were being drawn, by an Egyptian prince of a different mould (Ibrahim Pasha), who established stationary steam engines on his estates, which increased in fertility and value while the dykes, and the arches, and the canals, were in progress, with a view ultimately to foster harvests on the waste lands of the valleys, though in reality to bequeath fresh evidence—as if any were needed—of the truth that an idea may be theoretically grand and practically worthless. These Pharaonic works neither interested nor enlightened the poor peasants in whose behalf they were said to be undertaken. They simply served the purpose of a few speculators, and their destiny has culminated in a general swamping and downfall. Henceforth the latest trophies of the modern Pharaohs will present to the traveller's eye a few groups of unpicturesque fragments, scarcely coherent enough to tell the tale of their original design.

LOSS OF PRESSURE IN STEAM PIPES.

From "The Engineer."

It is well known that the initial pressure in a cylinder seldom equals the boiler pressure; certain exceptions to this rule exist, however, to which we shall refer presently. The loss of pressure is usually attributed to the frictional resistance of the steam pipe and condensation within the latter. There is reason to believe, however, that although such a deduction is consistent with facts in many cases, it is by no means always so. In other words, the proposition that friction and condensation in a steam pipe are the cause of a difference of pressure between the cylinder and the boiler is not invariably true under all circumstances and conditions. Indeed, there is reason to believe that in all cases when the steam pipe is of sufficient diameter the loss of pressure due to any influence which it can exert must be trifling. The question is one of growing importance, especially in our mining districts, because it is becoming more and more the practice to transmit steam from a boiler to an engine through very long distances. Pumping engines of great power are now fixed at the bottom instead of at the top of a shaft; and it is found to be more economical to take steam down the pit than to adopt heavy spears and plunger holes. If, however, it could be shown that any great loss of power and fuel must follow on the adoption of this system of construction, it might be better, after all, to resort to the old style of practice familiar to all engineers. It is somewhat remarkable that very few experiments have been made to determine what is really the effect of a long steam pipe on the power of an engine and the consumption of steam; and in the absence of experimental data, we must reason a good deal on theory in dealing with the question. Enough is known, however, to enable us to arrive at tolerably accurate conclusions as regards any given case.

In practice it is found that the difference between the pressure in the boiler and in the cylinder of stationary and marine engines is about 3 lbs. We have ourselves verified this fact dozens of times. The difference is sometimes a little more, sometimes a little less, but this may be taken as a fair average; and, curiously enough, it appears that the difference is very nearly independent of the boiler pressure. Thus, in an old-fashioned beam engine working with a boiler pressure of but 10 lbs., and having a piston speed of about 240 ft. per minute, the maximum indicated cylinder pressure was but a shade over 7 lbs. The steam pipe was short—about 15 ft. long—large and well clothed. In another case, with a boiler pressure of 70 lbs. and a steam pipe about 20 ft. long imperfectly protected, the initial pressure in the cylinder nearly reached 67 lbs. In a third instance, with about 20 ft. of well-felted 8-in. pipe, the initial pressure in the cylinder of an engine, 27 in. diameter, 3 ft. 6 in. stroke, running at 60 revolutions per minute, was 50 lbs., the boiler pressure being a little under 54 lbs. We could add many other cases to prove the accuracy of our proposition if they were required. Why it is that the difference is apparently independent of the pressure we are unable to explain in any way quite satisfactory to ourselves, so we must rest content with stating the fact. If any engineer will take the trouble to fit a steam pressure gauge on a valve chest, he will learn in two minutes that the received ideas of loss of pressure in steam pipes are erroneous—that is to say, if the pipe is of sufficient diameter. He will find that the hand of the gauge is in constant motion, falling with each opening of the steam port, and rising again when the valve closes. In single-cylinder engines, especially when working expansively, there is an intermittent flow of steam through the steam pipe. The moment the valve opens the steam in the valve chest rushes in, and the whole body of steam in the pipe has to be suddenly put in motion. Its inertia must be overcome, but before this can be done a considerable fall in pressure must take place in the valve chest and that part of the column next the engine; and it is not difficult to calculate exactly what this fall in pressure must be if we know the weight of steam in the steam pipe, and the required velocity. But at the moment the valve closes, the steam is in rapid motion. This motion is suddenly arrested, and the pressure in the valve chest may then, by the impact or momentum of the column of steam, rise considerably above that in the boiler for an instant. Mr. D. K. Clark cites cases in which the pressure in the valve chest was as much as 8 lbs. higher than that in the boiler from this cause. The difference between the initial pressure in the cylinder and that in the boiler appears to be in all cases almost wholly due to the resistance of the steam ports, and the inertia of the column of steam in the pipe, and little, if at all, to the resistance of the pipe or to condensation. Mr. D. K. Clark has found that the resistance of the steam pipe is quite inappreciable even in locomotives running at 600 ft. of piston per minute, when the sectional area of the steam pipe was not less than one-tenth of that of the piston; and Rankine states that, provided the velocity of the steam in a supply pipe is not suffered to exceed 100 ft. per second, the frictional resistance of the pipe may be entirely neglected. Of course it must be understood that we are taking no account of the resistance which may be due to the stop valve or throttle valve. If these are properly proportioned, they will, when wide open, in no way affect the results. As regards the resistance of the cylinder ports, and what is known as "loss of head," we shall do no more than refer our readers to "Rankine on the Steam Engine," page 414. We are now dealing with steam pipes, not with cylinder ports.

It is very commonly assumed that when a very long steam pipe is used there must be a great difference between the pressure in the boiler and the cylinder. This assumption, we believe, if used in the absolute sense, to be altogether erroneous. It is of course quite possible to make a steam pipe so small, and so full of bends and sharp turns, that it will cause considerable resistance and consequent loss of pressure; and it will be found, we venture to say, in all cases where a considerable loss of pressure does really take place, that the steam pipes are made too small and that the velocity of the steam is over 100 ft. per second. The temptation to make long steam pipes too small is very great, because the cost of a considerable length of steam piping is not a trifle. When the piping is large enough no loss of pressure worth mentioning will take place, even though the pipe be two or three hundred yards long, so far as frictional resistance can affect the question. There is only one other cause of loss of pressure, and this is condensation in the steam pipe, and this must of necessity be almost wholly inoperative to the assumed end. A little reflection will show that the length of steam piping suspended in air required to condense steam nearly as fast as a boiler can supply it, would be enormous. It is impossible, in short, for a steam pipe of any reasonable length to have much less pressure at one end than the other, provided the velocity does not exceed 100 ft. per second. We may regard the effect of condensation as being the same as though a second engine were put on. If as much steam was condensed as was used by the engine, then the consumption of steam at the further end of the pipe from the boiler would be practically doubled, and the required velocity would then be 200 ft. per second instead of 100 ft.; that is to say, if the pipe were properly proportioned to supply the engine only in the first instance, there would in the second be a small loss of pressure due to the increased velocity of the steam required to make up for condensation; but this would not be due directly to condensation, but to the fact that the steam pipe was too small for its work. The remedy is obvious. Let the steam pipe be protected and the loss of pressure will become little or nothing. One of the best means of protection is to lay the steam pipe underground in large wooden troughs, waterproof if the ground be damp, the troughs to be filled with dry sawdust or fine dry sand. If this arrangement be inadmissable, then the pipes should be covered with felt, or some one or other of the various compositions for the purpose in the market. The loss by condensation may in this way be reduced to one or two per cent. of the whole quantity of steam used by the engine. A pipe 12 in. in circumference and 200 ft. long would have 200 square feet of surface, and the total quantity of steam which such a pipe would condense if exposed unlagged to air at 60 deg. would not exceed about 72 lbs. per hour. But the sectional area of such a pipe inside would be about 9 in. A cubic foot of steam would occupy 192 in., or 16 ft. of its length, and at 100 ft. per second, the tube would pass 6.25 cubic feet per second, or 22,500 cubic feet per hour. The weight of this steam, taking it at 50 lbs. pressure above the atmosphere, would be 4,017 lbs. Assuming that the engine used 60 lbs. per horse-power per hour, this would represent over 66 horse-power, and as the loss by condensation would not exceed 72 lbs., it will be seen that it is ridiculous to talk of condensation in the pipe as a cause of loss of pressure. In a word it may be stated that loss of pressure in a long steam pipe can only take place as a result of the frictional resistance of that pipe to the fluid moving within it; that sharp bends materially increase the resistance; but that if the pipe is tolerably straight and sufficiently large, the frictional resistance will be almost inappreciable; in no case can condensation be a cause of loss of pressure unless the pipe is exposed uncovered to rain, or water in some other form, and that the loss of pressure will then be due, not to condensation, but to the fact that those portions of the pipe near the boiler will be too small to supply the extra demand for steam at the other end of the pipe, unless the steam flows at such a velocity that the frictional resistance of the pipe will operate prejudicially. It is not to be denied, however, that in many instances in practice there is a very serious loss of pressure between the engine and boiler in long pipes. In all such cases, however, the pipes are too small for their work, or they are improperly fitted. We can call to mind one which came under our own knowledge, where the difference in pressure between the boiler and the engine, with a 3-in. pipe about 12 ft. long, was as much as 12 lbs. The engine had only just been started; the stop valve was held to be guilty, and was changed for one larger. This did no good. Then new steam pipes were ordered, and when the old one was taken down it was found that the whole cause of the mischief lay in the fact that the man who put the pipes up, in making a flange joint, used a ring wrapped with tow and red lead. The inner diameter of the ring, instead of being 3 in., was little more than 1 in. The joint was remade as it should be, the pipes re-erected, and there was no more trouble. Nothing is more common at collieries and mines than the use of long steam pipes made of any kind of tubing at hand, and of varying diameter, but invariably too small. Then we hear of loss of pressure, and it is on no better basis than this that the whole theory of pressure being lost if a steam pipe is long has been built up. In designing steam pipes, as well as any other appurtenance of a steam engine, nothing is more easy than to make a mistake. If we can induce our readers to think twice before they settle the proportions of their steam pipes, our purpose in writing this article will have been served.

THE FORM AND CONSTRUCTION OF SEWERS.*

From "The Architect."

The author, after referring to the water, earth, and air systems of removing sewage, stated that when the water system is properly planned, executed, and taken care of, it works most satisfactorily, and that when there is deposit and smell at any part it is invariably caused by malformations, faulty execution, neglect, or the absence of some necessary appliance. As the water system derives the requisite power to remove the sewage matters from the form, fall, size, and construction of the channels, it is imperative that by no defect in these should any of this power be wasted or lost. At different periods various forms have been used for drains and sewers. The best is that of an egg, broad at the large end, and narrow at the small end, and this end placed downward. The egg-shape and the circle are now generally employed for large brick sewers, and the circle for pipe sewers and drains. Thirty years ago two large sized sewers were in use in the Westminster district. The form was nearly flat-bottomed, with upright sides and semi-circular crown; and the work was badly executed, especially in the inverts, where the bricks were usually laid dry. Before this form was introduced sewers were built with flat bottoms. Hundreds of miles of these sewers now exist in the metropolis, the bricks being porous, the mortar friable, the work rough, and the gradients extremely irregular. In the Westminster district there are 150 miles with slightly curved and flat bottoms. Through these the greater part of the sewage constantly leaked, saturating the ground, and leaving the solid matters behind upon the surface. During the author's examination of these sewers he found sewage deposits in nearly all of them, varying in depth from two or three inches to two or three feet. This was caused by the large width and flatness of the bottoms spreading and destroying the flow, by the bottoms permitting the liquids to pass through them like sieves, and by the street detritus collecting in small heaps opposite the gully drains and pressing back the sewage. Thus the sewers formed a network of extended cesspools, which were emptied at intervals when the accumulations stopped the house drains, and the decomposing filth sent up streams of noxious gases into the air through the gully and house drains, which at this time were defectively trapped and unventilated. The remedy for this state of things appeared to the author to consist in making the channels narrow, even, smooth and watertight, and in providing the inlets with syphon-taps and ventilating pipes. He took care that the sewers

*A paper read before the Society of Engineers, London, by John Phillips, C. E.

put in under his superintendence should be solidly and tightly constructed. This slightly increased the velocity of the flow, but the excessive width and flatness of the bottoms diffused the streams so much that they were unable to lift and carry away the sewage matters. What, therefore, appeared to the author necessary to ascertain was the form of channel that would give the sewage the utmost velocity, and the rate of velocity at which the sewage must travel to raise and keep the matters in suspension and carry them to the outfalls.

He therefore made four channels along the old sewers, namely, a semi-circle, an elliptic segment, a parabola, and a hyperbola, and for months he measured and computed the velocities of the sewage running in them. It resulted from his experiments that the velocity was greater in the elliptic segment than in the semicircle, in the parabola than in the elliptic segment, and in the hyperbola than in the parabola. This was evidently due to successively contracting the bottoms of the channel, which, by successively increasing the depth of the stream, increased its slope at the surface, and thus, by giving it greater gravitating energy, increased its velocity and scour. He also found that sharp curved side walls with a large batter resisted lateral pressure better than flat curved side walls with a small batter, and that a prolate elliptical arch sustained vertical pressure better and gave more headway than a semicircle. Combining these results, he produced an egg-shaped sewer, which was adopted by the Westminster Court of Sewers in place of the old form with a nearly flat bottom and upright sides. This was in 1846. Soon after this he introduced an egg-shaped sewer, with the same invert, but with a semicircular crown. This form has been in use ever since in the metropolis, as also throughout Great Britain, Europe, India, and America. The author stated that owing to the quantity of sewage running in the sewers each day, varying from a minimum to a maximum flow, the channels should be made in accordance with the increment of the flow, that is, parabolic or hyperbolic, and not semicircular. By this means the minimum flow, and the stream at all depths up to the maximum flow, would have much greater velocity. This applies to all channels for the conveyance of sewage from the smallest drain to the largest outfall sewers.

The construction of brick and concrete sewers was then reviewed. They should be built accurately to the inclination and curvature, thoroughly solid and watertight, and perfectly even, smooth and regular. By particularly attending to these essential points, distortion and leakage are prevented, and the flow is accelerated. Bricks only of the very best quality, and Portland cement, which is almost proof against the chemical action of sewage, should be used. Concrete sewers are jointless and non-absorbent, and are stronger and more durable than brick sewers. Three courses of solid fireclay blocks in long lengths should be used along the bottoms. The use of hollow blocks at this part, where the weight of the sewer and of the ground pressing upon and against it is concentrated, is a mistake, for this weight causes such blocks to crack and break. Moreover, they let the sewage out of and the subsoil water into the sewer. Where the body of sewage or the inclination is small, the sand and other substances which are washed into the sewers become mixed with the excretæ, fat, hair, paper, and other matters, and form concrete masses along the bottoms, which no current or flush of water can tear up or remove. For this reason detrital substances should be kept out of sewers and drain channels as much as possible. This is to be done by making catch-pits under the sinks and gullies, and taking care to empty them after every rainfall. Much of the evils arising from deposit in and smell from drains and sewers is caused by not providing these necessary appliances, and in neglecting to employ them where they are provided. The author first introduced syphon-trapped catch-pits under the gullies in the metropolis in 1848, and they have been generally used in towns ever since. As sewage is charged to its maximum capacity with comminuted organic and inorganic matters, it must flow at a certain rate of velocity to hold the sediment in suspension and carry it with the detritus to the outfalls. From 1844 to 1846, inclusive, the author measured and computed the sewage running in the Westminster sewers, both where there was deposit and where there was none, and it resulted, from his experiments, that where there was deposit the velocity of the flow was less, and where there was no deposit the velocity was more than 2½ feet per second. Whether the flow or the inclination was large or small, so long as the sewage travelled at this rate of velocity the sedimentary and other matters were completely carried away. This result threw a new light on the science of sewage. The author first enunciated this principle in 1847 before the Sanitary Commission. It was quoted by Beardmore, adopted by Bazalgette in arranging the gradients for the main drainage of the metropolis, and engineers have ever since regulated the inclination of sewers in accordance with it. Where the body of sewage or the inclination is sufficient to produce this velocity, there is no need to provide for flushing; but where the one or the other is insufficient to generate the required velocity, deposit will ensue and accumulate unless it is flushed away.

A quarter of a century ago the greater part of the sewers of the metropolis were found to be sewers of deposit. Ample data were then obtained from which a general plan could have been laid down for making nearly all of them self-cleansing with the common run of sewage. The flushing system, however, was adopted, and is still in use. At the present time there are about 600 miles of sewers in the metropolis which would choke up if they were not regularly flushed. It is a popular fallacy among the uninitiated that the main drainage has effectually improved these sewers. In no way have they been improved by it. Hence they accumulate deposit now just the same as they did before the main drainage was begun, and they will continue to do so until contracted hyperbolic channels are laid down along the old inverts. The author proposed this plan in 1847 before the Sanitary Commission, but a general system of flushing was adopted instead. The plan has since been tried in some deposit sewers, which have by its means been changed into self-cleaning sewers. About £330,000 have been expended during the last quarter of a century in flushing. This is at the rate of £13,200, or one penny per foot level, per annum. The cost of laying down new hyperbolic channels as proposed would be about 3*s.* 9½ *d.* per foot run, or £1,000 per mile. Consequently the cost of the 600 miles would be £600,000. The amount expended annually for flushing would pay off the principal and interest of this amount in thirty years, or the money could be raised from the coal tax. Stoneware pipes are generally made circular, but it would be a great improvement to make the inverts hyperbolic and the chevrons semicircular. The minimum flow would then have less frictional surface, more depth and more velocity, and the velocity at all depths up to the maximum flow would be greater. If the form which generates the utmost velocity is to decide which channel is best for the conveyance of sewage, then, unquestionably, the hyperbolic channel is far superior to the semicircular, and should be used instead. But it has been urged as an objection to employing pipes of any other shape than circular for sewers and drains that, owing to the distortion which takes place during the drying and burning of the clay, they cannot, while being laid, be made to fit each other so well at the joints as the circular pipes, which can be turned round until the convex distortion in one pipe fits the concave distortion in the other. Hence perfection of form, evenness of surface, and increase of velocity are sacrificed because of the distortion which is unavoidable in the manufacture of these pipes. Also, owing to the irregular shape of and large space in the sockets when the pipes are put together, they never fit each other so as to produce concentricity, but protrusions are formed round their interior, which may be seen by laying a few pipes together on a board. Moreover, owing to the difficulty of getting to the under side of the joints, they cannot at this part be made water-tight without great care and supervision. The gaping openings at the side and top of the joints also allow the cement used in stopping them to squeeze through, drop on the bottom, or form frills round the inside, causing obstructions and reducing the bore of the pipes. Another drawback to the production of even, regular, and efficient channels for the conveyance of sewage by stoneware pipes is their short length of two feet. Engineers should specify them three feet and even four feet long. The advantages would be that there would be a less number of joints, or rather points of leakage, the pipes could be laid truer to the line and gradient, and the velocity of the sewage would be unchecked and increased. With a view to remedy the defects in the joints of those pipes, the author has recently invented a new joint, which can be easily made perfectly tight against leakage, and will ensure concentricity of the pipes, and of their being solidly laid. This invention he has no doubt will accomplish what has been so long desired, to make stoneware pipes concentric and watertight. Pipes, however, can be manufactured of Portland cement truer of shape, much longer, and consequently with fewer joints, and stronger and more durable than stoneware pipes. Portland cement sets and becomes intensely hard, which goes on increasing indefinitely. It also resists compressive and tensile strains much more than vitrified stoneware. On the Continent such pipes are largely used, and most excellent pipes they are. With Portland cement pipes, made as the author suggests, laid in straight lines to regulate inclinations, and tightly jointed as he describes, we should obtain perfectly formed sewers and drains, uniform of section, even of surface, and tight at the joints, which are the desiderata for channels for the conveyance of sewage.

THE NEW METHOD OF "GRAPHICAL STATICS."

By A. J. DUBOIS, C. E., Ph. D.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE object of the following pages is to call more general attention to a new method for the graphical solution of statical problems, which has during the last ten years, mainly in Germany, been gradually developed and perfected, and which offers to the architect, civil engineer, and constructor a simple, swift, and accurate means for the investigation of a great number of practical questions. When once thoroughly understood and familiarized, it will be found greatly superior to the graphic methods at present in general use. Thus, for instance, in the determination of the *centre of gravity* and *moment of inertia* of areas and solids; of the resultant of forces either in space or in the same plane, and having the same or different points of application, as also in the resolution of forces generally, the method alluded to will be found of easy and universal application. When applied to determine the strains in the various members of a roof truss, bridge girder, or similar framed structure, it furnishes a system of "diagraming" which can be applied independently of any special assumptions as to load distribution, which gives the strain in each member by a single line, which is simple and rapid of execution, and which checks its own accuracy.* In its application to "*continuous girders*" it furnishes the *only* method of complete solution for variable loading, without calling in the aid of the higher analysis, or having recourse to intricate formulæ and wearisome calculations. Thus, a girder continuous over three or more supports, at different elevations, and sustaining a "concentrated load" at any point, can be investigated with nearly the same ease and accuracy as one resting upon only two supports. Here especially those already familiar with the analytical method can, by a union of the two, greatly shorten the time and labor usually consumed in such cases.

To Prof. Mohr, of the Stuttgart Polytechnicum,* the new method owes its origin, as well as many of its most important improvements and extensions. But it was not till 1866 that the complete and systematic presentation of the subject by Culmann† directed general attention to the subject, and excited general interest.

During the eight years which have since elapsed, the method has been considerably extended, notably in the treatment of continuous girders above referred to, and the new edition of Cullmann's original work, which is soon to appear,

* *Iron Bridges and Roofs*, Unwin. London, 1869; p 127.

* *Zeitschrift des hannov.* Arch. u. Ing. Ver. 1860 and 1868-70.

† *Die Graphische Statik.* Zurich, 1866.

and which has been so long promised, is looked forward to in Germany with considerable interest.

Admirable as Culmann's treatment of the subject undoubtedly is, still for a long time this interesting and useful method failed to meet with that appreciation and recognition from professional men to which it had such just claims; partly, perhaps, because of a natural disinclination in old practitioners to relinquish well known and familiar methods, and partly because the treatment of Culmann required for its comprehension a knowledge of the so-called "Modern Geometry," or *Theory of Transversals.*

This method of treatment is, however, by no means necessary. The system admits of a clear and logical development, which can be followed and apprehended by any one familiar with the elements of geometry as generally taught; and to give in just such a manner the outlines of the subject, indicating its most important applications, and thus to bring it within the reach of those in this country for whose benefit it seems so especially designed, is the purpose of these pages.

1. Notation, etc.—In order that a force may be "given" or completely determined in its relations to other forces, we must know not only its *intensity*, but also its *direction*, and the position of its *point of application.* These three being known, the *geometrical* expression of our knowledge is very simple. We have only to assume a certain *length* as the *unit* of force, and then any force is at once given by the *length, direction, and position of a straight line.* This method of force representation is so obvious, that it is in fact used in mechanics, even where the treatment itself is essentially analytical.

Unless expressly stated, all the forces with which we have to do in these articles will be considered as lying and acting in the *same plane.* Graphically then, any force is completely determined by a straight line, the beginning of which represents the point of application, and the length and direction of which give the intensity and direction of the force.

We shall indicate a force in general by the letter P, its point of application by A. When we have several forces we represent the points of application by A_1, A_2, A_3, etc., and the *ends* of the corresponding lines by P_1, P_2, P_3, etc. The direction in which a force is supposed to act is thus unmistakably indicated.

When, however, lines representing several forces are laid off one after another, the beginning of each at the end of the preceding, it will be sufficient to put 0 at the beginning of the first, and 1, 2, 3, etc., at the end of each. No confusion can arise, as each force acts and reaches from the point indicated by the figure which is one *less* than its index, to the point indicated by that index.

When, finally, we designate a force by the two letters or figures which stand at the beginning and end, we shall always indicate by the *order* in which the letters or figures are written, the direction of action of the force, first naming the point of application, and then the end.

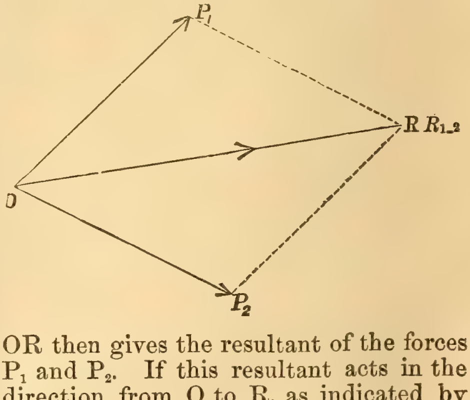
A force due to the composition of several forces, as P_1, P_2, P_3, we denote by $P_{1\text{-}3}$ or $R_{1\text{-}3}$. Thus $R_{1\text{-}3}$ denotes the *resultant* of the forces P_1, P_2, and P_3.

Chapter I.

FORCES IN THE SAME PLANE—COMMON POINT OF APPLICATION.

2. If two forces, P_1 and P_2, given in direction and intensity by the lines OP_1 OP_2 [Fig. 1], have a common point of application O, the resultant $R_{1\text{-}2}$ is found by the well known principle of the "parallelogram of forces," by completing the parallelogram as indicated by the dotted lines, and drawing the diagonal.

Fig. 1.



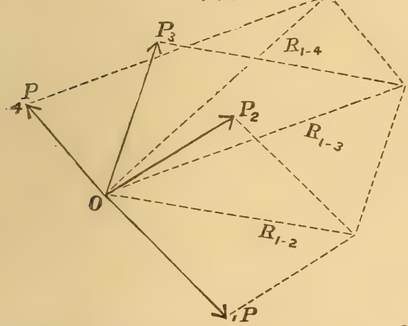
OR then gives the resultant of the forces P_1 and P_2. If this resultant acts in the direction from O to R, as indicated by the arrow, it *replaces* P_1 and P_2; that is, it produces the same effect as both forces acting together. If it were taken as acting in the opposite direction—*i.e.*, from O outwards, *away* from R—it would hold the forces P_1 and P_2 in *equilibrium*.

Now, we see at once that it is *unnecessary to complete the parallelogram*. It is sufficient to draw from the end of the force P_2 the line P_2 R *in the same direction that* P_1 *acts in*, and make it equal and parallel to P_1. The point R thus found is the end of the resultant R, or is a point upon the direction of the resultant prolonged through O.

As to the *direction* of action of the resultant. If we follow round the triangle from O to P_2 and from P_2 to R and R to O—*i.e.*, if we follow *round in the direction of the forces*—the direction for the resultant from R to O thus obtained is, as we have already seen, the direction necessary for *equilibrium*.

3. If, instead of two forces, we have three or more, as P_1, P_2, P_3, P_4 [Fig. 2] we still have the same construction. Thus completing the parallelogram for P_1 and P_2 we find $R_{1\text{-}2}$. Completing

FIG. 2.



the parallelogram for $R_{1\text{-}2}$ and P_3, we find $R_{1\text{-}3}$, and again, with this and P_4 we obtain $R_{1\text{-}4}$. Again, we see it is unnecessary to complete all the parallelograms. We have only to draw lines P_1 $R_{1\text{-}2}$, $R_{1\text{-}2}$ $R_{1\text{-}3}$, $R_{1\text{-}3}$ $R_{1\text{-}4}$, parallel to the forces P_2 P_3 and P_4 respectively, and equal in length to the intensities of these forces, and then, no matter what may be the number of forces, the *line drawn from the point of beginning to the end of the last line laid off* will give the intensity and position of the resultant. As to direction, the same holds good as before.

If the end of the last line laid off should coincide with the point of beginning, there is, of course, *no* resultant, and the forces themselves are in equilibrium.

The polygon formed by the successive laying off of the lines parallel and equal to the forces, we call the "*force polygon.*" Hence we have the following principles established:

If any number of forces having a common point of application and lying in the same plane, are in equilibrium, the "force polygon" is closed.

If the "force polygon" is not closed, the forces themselves are not in equilibrium, and the line necessary to close it gives the resultant in intensity and direction.

This resultant, if considered as acting in the direction obtained by following round the "force polygon" with the forces, will produce equilibrium—acting in the opposite direction, it replaces the forces.

The resultant thus found in intensity and direction can be inserted in the *force diagram* at the common point of application.

5. Thus, required the position, intensity, and direction of the resultant of the forces P_1, P_2, P_3, P_4, P_5.

These forces are given in position, direction, and intensity by the *force diagram*, Fig. 3 (a). The resultant of all these forces must have of course the same point of application A as the forces themselves—it remains to find then its relative position and the direction of its action, so that we may properly insert it in the *force diagram*.

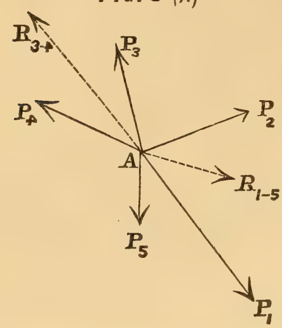
We have simply to draw the *force polygon*, Fig. 3, (b) by laying off successively O, P_1, P: P_2, etc., equal, parallel, and in the same direction as the forces P_1, P_2, etc., as given by Fig. 3 (a). Then the line P_5 O necessary to close the force polygon gives the intensity of the resultant, and in order to replace $P_{1\text{-}5}$ it must act in the *direction from O to* P_5; *i. e.*, contrary to the order of the forces. If then in Fig. 3 (a) we draw A R equal and parallel to O P_5, we have the resultant applied at the common point of application A, and given in position, intensity, and direction.

Moreover, it is evident that *any diagonal* of the force polygon as $R_{3\text{-}4}$ [Fig. 3 (b)] is the resultant of $P_{3\text{-}4}$, and acting in the direction from P_4 to P_2, it holds $P_{3\text{-}4}$ in *equilibrium*. But it is also the resultant of P_1, P_2, P_5, and $R_{1\text{-}5}$, and acting in the same direction as before, it *replaces* these forces. The force polygon thus shows that the force which *replaces* P_1, P_2, P_5, and

$R_{1\text{-}5}$, at the same time holds P_3 and P_4 in *equilibrium*, just as it should be.

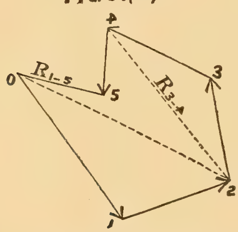
If, on the other hand, we had originally only P_1, P_2, $R_{3\text{-}4}$, P_5, and $R_{1\text{-}5}$ forming a system of forces in equilibrium, we could *decompose* $R_{3\text{-}4}$ into two components by simply assuming any point as P_3 [Fig. 3 (*b*)] and drawing $P_3\,P_4\,P_3\,P_2$. Then following round this new polygon in the direction

Fig. 3 (A)



of the forces, or, what amounts to the same thing, taking the direction of the components P_3 P_4, *opposed* to the direction of $R_{3\text{-}4}$ for equilibrium, we obtain the direction of action of P_3 and P_4 as shown by the arrows in Fig. 3 (*b*). These forces

Fig. 3. (B)



inserted in Fig 3 (*a*), *in the place* of $R_{3\text{-}4}$ and in these directions, will not disturb the equilibrium.

Hence, *any diagonal in the force polygon is the resultant of the forces on either side, holding in equilibrium those on one side and replacing those on the other, according to the direction in which it is conceived to act.*

Also, *any force or number of forces may be decomposed into two others in any desired direction, by choosing a suitable point in the plane of the force polygon and drawing lines from this point to the beginning and end of the force or force polygon.*

6. It matters not in what order we lay off the forces in the construction of the force polygon.

Thus, in Fig. 1, whether we draw from the end of P_2 the line P_2, $R_{1\text{-}2}$ equal and parallel to P_1 or from the end of P_1 the line P_1 $R_{1\text{-}2}$ equal and parallel to P_2, in either case we obtain the same resultant and the same direction for the resultant. But by a similar change of two and two, we can obtain any order we please. For example, we lay off in

Fig. 3. (C)

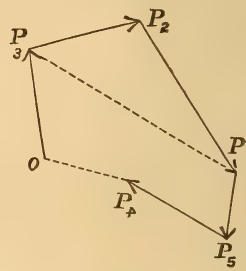


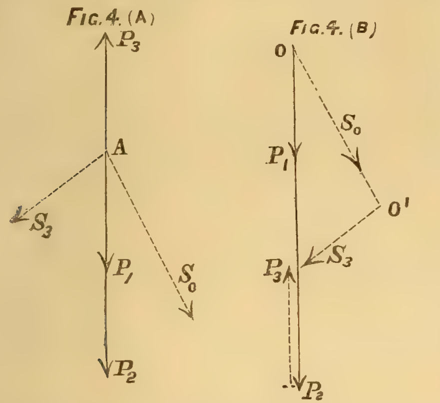
Fig.3 (*c*) the same forces in the order $P_3P_2P_1$ P_5 P_4, and obtain precisely the same resultant, in the same direction as before. For, the resultant of P_3 and P_2 must be the same as that of P_2 and P_3 in the first case. The resultant of $R_{3\text{-}2}$ and P_1 must then be the same in both polygons, and so on.

Generally, then, no matter what the order in which the forces are laid off, the line necessary to close the force polygon is the resultant of the forces, and the diagonals of the force polygon give us the resultants of the forces on each side.

By assuming a point at pleasure, and drawing lines from this point to the beginning and end of any side of the force polygon, and taking the direction of these lines *opposed* to the direction of that side, we can *decompose* any force in the force polygon into its components. Thus the force polygon gives us complete information as to the action of the forces.

7. If the forces act in the same straight line, the force polygon of course becomes a straight line also, and the resultant is the sum or difference (algebraic sum) of the forces.

Thus, if we have P_1, P_2, P_3 all acting at the point A, as shown by the force diagram Fig. 4 (*a*), we form the force polygon by laying off from O Fig. 4 (*b*) the intensity of P_1, from the end of this line P_1 P_2 equal to A P_2 and from P_1, P_2, P_3 equal to A P_3 Then the line necessary to close the polygon is evidently $O P_3 = P_1 + P_2 - P_3$. A single force acting then at A in the direction of and having the intensity repre-



sented by the line O. P_3 would replace P_1, P_2, and P_3. If acting from P_3 to O, it will produce equilibrium.

If we again choose an arbitrary point as O^1 [*we shall hereafter call this point the "pole" of the force polygon*], and draw lines S_0 S_3 from this *pole* to the beginning and end of the force polygon, we can decompose the resultant into two forces in any required direction. If the resultant is supposed to act down, then the arrows show the direction in which these components must act in order to *replace* the resultant. If then at A we draw lines parallel and equal, we have these components in position, direction, and applied at the common point of application.

PRACTICAL APPLICATIONS.

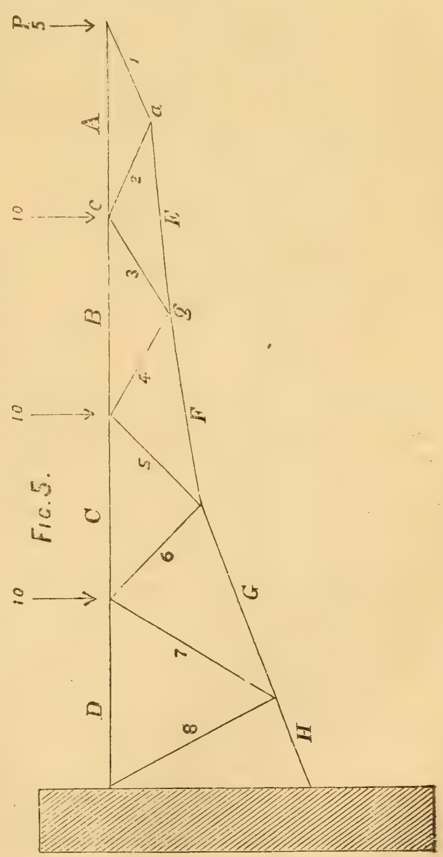
8. Simple and even self-evident as all the preceding may seem, we have already acquired all the principles requisite for a rapid, accurate, and very elegant method of finding by diagram the strains in the various members of all kinds of framed structures, such as roof trusses, bridge girders, cranes, etc., no matter how complicated the structure, or what special assumptions are made as to the loading, provided only, that all the exterior forces are known. A complicated or unsymmetrical arrangement of parts increases greatly the labor of calculation, but has no effect upon the ease or accuracy of the graphical method. The method moreover checks its own accuracy, does not accumulate errors, and shows in one view the *relation* of the strains to each other, and the variations which would be caused by a change in the manner of load distribution, or in the form of construction.

As this method is not as well known as it deserves to be, it will perhaps be of advantage to pause for a moment in the development of our subject, and make this direct application of the principles already established.

BRACED SEMI-ARCH.

9. Stoney, in his "Theory of Strains," Vol. I., page 123, gives the following example of a "braced semi-arch," represented by Fig. 5. The dimensions are as follows: projecting portion, 40 ft., long 10 ft. deep at wall. Lower flange, circular, with a horizontal tangent 2 ft. below the extremity of girder. Radius of lower flange, 104 ft. Load uniform and equal to one ton per running foot supposed to be collected into weights of 10 tons at each upper apex, except the outer one, which has only 5 tons.

Fig. 5 shows the Arch drawn to a scale of 10 ft. to an inch.



This scale is too small in this case to ensure good results; in general the larger the scale to which the *frame* can be drawn, the better; but for the purpose of illustration it will answer well enough. With a large scale for the *frame diagram*, a scale of 10 tons to an inch will in general be found to answer well. Fig. 5 (*a*) gives the strains in the various members to a scale of 10 tons to an inch and Fig. 5 (*b*) 20 tons to an inch; the first for the load at the extremity alone, the second for a uniform load.

Fig. 5 (*a*) is thus obtained. We first lay off the weight, 5 tons, to scale, in the direction in which it acts; *i.e.*, *downwards.* Now this weight and the strains in dia-

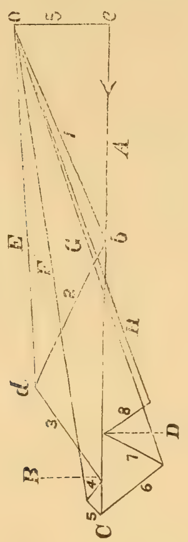


Fig. 5. (A)

gonal 1, and flange A, are in *equilibrium;* therefore by article (4) the force polygon must close. Drawing lines therefore from the ends of the line representing the weight 5 tons, parallel to these pieces and prolonging them to their intersection, we obtain the strains in A and 1. Commencing with the beginning of the weight line and following *down* around the triangle thus formed, we find that A acts from right to left, as shown by the arrow. A acts then *away* from the apex; it is therefore in *tension.* Diagonal 1 acts *towards* the apex and is *compressed.*

We pass now to apex *a*, of the frame. Here we have the strains in E and diagonals 1 and 2, and these three strains hold each other in equilibrium. The strain in 1 we have already, and know it to be *compressive.* We have then simply to draw lines parallel to E and 2, and follow round the triangle, to obtain the intensity and quality of the strains in E and 2. We must remember that as 1 is in compression, and we are now considering apex *a*, we must follow round from *o* to *b* in Fig. 5 (*a*), and so round. We thus find 2 acting *away* from apex *a* and therefore in *tension*, and E acting towards this apex, and hence *compressed.*

Pass now to apex *c.* We have the

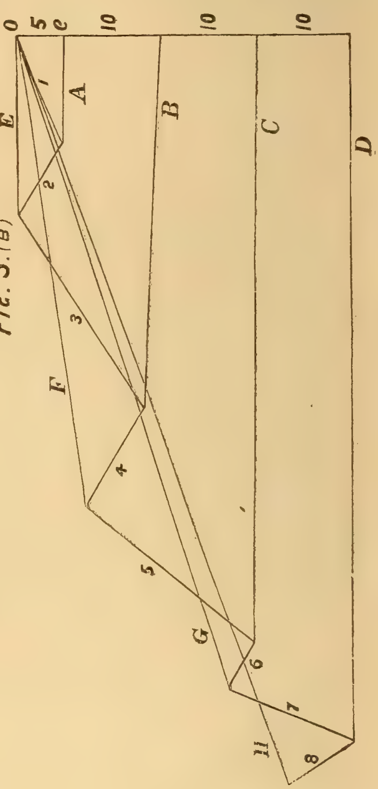


Fig. 5. (B)

strains in A and 2 in equilibrium with B and 3. [No weights are supposed to act except the one at the end.] But A and 2 we already have. We draw 3 and B. Diagonal 2 has been found to be in tension. With reference to apex *c* it must therefore act *away* from *c; i. e.*, from *d* to *b* in the force polygon. This is sufficient to give us the hint how to follow round. We pass from *d* to *b* for 2, from *b* to *e* for A, then from *e* to B and from B to *d* for B and 3. B is therefore *tension* and 3 *compression.* And so we proceed. For the next apex *g*, we have E and 3 in equilibrium with F and

4. We draw parallels to F and 4 so as to close the polygon of which we have already two sides, E and 3, given, and remembering that as 3 is in compression and must therefore act *towards g*, we follow round the completed polygon with this to guide us, and find 4 *tension* and F *compression*. Thus we go through the figure, and when all is ready we can scale off the strains. The strains in the lower flanges it will be observed all radiate

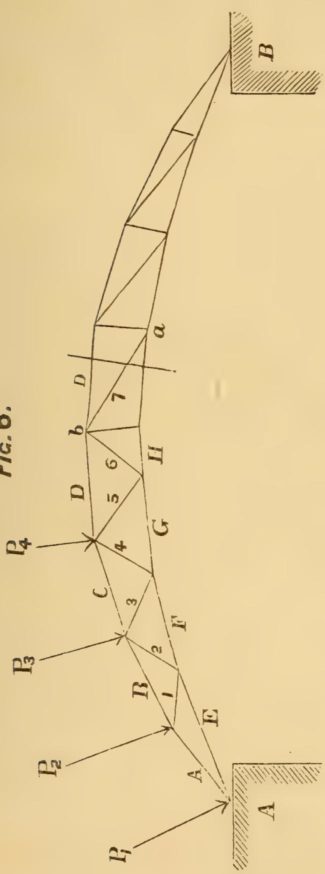


Fig. 6.

from *o*. The upper flanges are all measured off on the horizontal *e* C, and the diagonals are the traverses between. We see at once that however irregular the structure, we can always easily and readily determine the strains at any apex, *provided no more than two unknown strains are to be found.* If more than two pieces, the strains in which are unknown, meet at an apex, we can evidently form an indefinite number of closed polygons. The problem is indeterminate, and the structure has unnecessary or superfluous pieces.

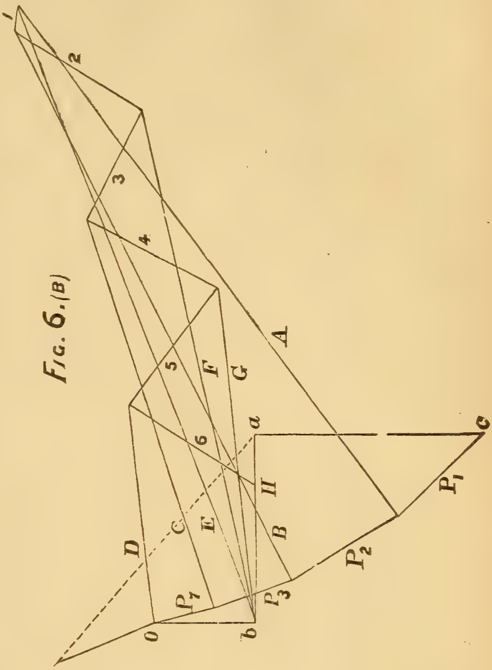


Fig. 6. (B)

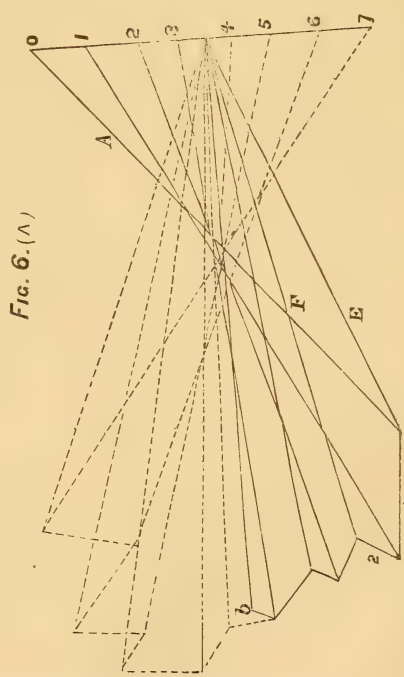


Fig. 6. (A)

Fig. 5 (*b*) gives the strains for a uniform load, taken, for convenience of size, to a scale of 20 tons to an inch. Here until we arrive at apex c of the frame the strains are evidently the same as before. Observe the influence of the weight at c. Here we have the strains in A and 2 given in the diagram, in equilibrium with B, 3 *and the known weight* acting at c; viz., 10 tons. We lay off therefore 10 tons *downward* from e Fig. 5 (b), and follow *down* from e around the polygon. We thus find B tension and 3 compression. Then 4 and F are found as before for apex g, 4 tension and F compression; and then we come to the next apex and the *next weight.* This is laid off downwards from the end of the preceding, and then we follow round, finding C tension and 5 compression; and so on.

10. As another example, let us take the

ROOF TRUSS,

given in Fig. 6. This truss is given by Stoney, Vol. I, page 128. Dimensions: span, 80 ft.; rise of top and bottom flanges, 16 and 10 ft. respectively. Radii, 58 and 85 ft. The figure shows two different kinds of bracing. In the left-hand part the extreme bay of the lower flange is half as long again as the others. The upper flange is divided into 4 equal bays. In the right-hand section, both flanges are divided into 4 equal bays, and every alternate brace is therefore nearly radial. Each upper apex in both cases is supposed to sustain a weight of one ton.

The strains in the various pieces are given in Fig. 6 (a).

We form the force polygon by laying off the weights from 0 to 7 and then laying off the reactions 3.5 apiece, upwards, we come back to 0, and the force polygon is closed as it should be, since the sum of the reactions must be equal and opposite to the sum of the weights. Starting then with the reaction at the left support A, we go through from apex to apex in a manner precisely similar to the previous case. The operation is so simple that it is hardly necessary to detail it again, but we recommend the reader to go over it with the aid of Fig. 6 (a), lettering the figure as he proceeds. The dotted part gives the strains for the right-hand half.

DIAGRAM FOR WIND FORCE.

11. It is of considerable importance to investigate the influence of a partial load, such as that caused by the wind blowing on one side of the roof, and this by the aid of our method we can easily do.

From the experimental formulæ of Hutton,*

$$P_n = P\sin i^{1.84\cos i - 1}$$
$$P_h = P\sin i^{1.84\cos i}$$
$$P_v = P\cot i \sin i^{1.84\cos i}$$

where P is the intensity of the wind pressure in lbs. per sq. ft. upon a surface perpendicular to its direction, i is the inclination of any plane surface to this direction; P_n is the normal pressure, P_h the horizontal component of this normal pressure, and P_v its vertical component.

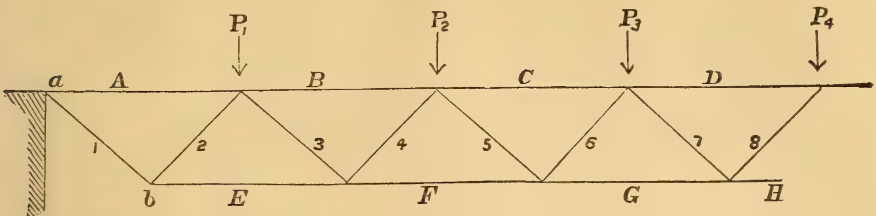
That is, if the wind blows horizontally, P_h is the horizontal and P_v the vertical component of the pressure on the roof. If we take P=40 lbs., which probably allows sufficient margin for the heaviest gales, we have the following values of the normal pressure and its components for various inclinations of roof surface:

Angle of Roof.	Lbs. per square foot of surface.		
	P_n	P_v	P_h
5°	5.0	4.9	0.4
10°	9.7	9.6	1.7
20°	18.1	17.0	6.2
30°	26.4	22.8	13.2
40°	33.3	25.5	21.4
50°	38.1	24.5	29.2
60°	40.0	20.0	34.0
70°	41.0	14.0	38.5
80°	40.4	7.0	39.8
90°	40.0	0.0	40 0

The load at each joint may be taken as equal to the pressure of the wind striking a surface whose area is equal to that portion of the roof supported by one bay of the rafter, and inclined at the same angle as the tangent to the rib at the joint. Thus we can calculate P_1, P_2, P_3, and P_4, [Fig. 6], resolve these forces into their horizontal and vertical components, and find the reactions at the supports as well as the horizontal force at the left abutment, which in our construction is supposed to be fixed. Should the wind be supposed to blow from the right side, the strains would be entirely different, and it would be necessary to form a second diagram. Each piece must be proportioned to resist the strains arising in either case. The forces P_{1-4} and their horizontal and vertical components, as also the reactions, being known, we can now form the force polygon.

Iron Bridges and Roofs. Unwin. P. 120.

FIG. 7.



In Fig. 6 (*b*) we lay off the forces P_{4-1}, make *a c* equal to the vertical reaction at A, *a b* = the sum of the horizontal components, or the horizontal force at A, and *o b* the vertical reaction at the right support. This last line should close the force polygon and bring us back to *o*.

Now starting at the left support, we have the vertical reaction *a c*, the horizontal force *a b*, and the wind force P_1, in equilibrium with A and E. Closing the polygon by lines parallel to A and E, we obtain the strains in these pieces, E tension and A compression. At the next apex we have A and P_2 in equilibrium with 1 and B. Completing the parallelogram, we find 1 compression and B compression. At the next apex 1 and E are in equilibrium with 2 and F, and we find F and 2 tension, and so on. The upper flanges are in compression and start from the ends of the forces P_1, P_2, etc. The lower flanges radiate from *b*. If we were to carry out the construction for the rest of the frame, the upper flanges after D would radiate from *o*.

A comparison of Fig. 6 (*a*) and (*b*) shows that whereas under uniform load the strain in 1 is *tension*, for wind force the same brace is in *compression*. In fact in the first case *all* the braces are in tension, while in the second 1, 3, and 5 are compressed, and 3 and 5 quite severely. The strains in the bracing generally are much greater in the second case.

Were we to consider the wind as blowing from the other side, or what is the same thing, suppose the right end fixed and the left supported on rollers, then the horizontal reaction *a b* will be applied at the right abutment. In this case the lower flanges will radiate from *a* instead of *b*, and the first upper flange will start from *o*. Supposing the first two lines of this new diagram drawn, as indicated by the dotted lines, and following round from *b* to *o*, and so round to *a* and back to *b*, it may easily happen that the last upper flange is in *tension* and the last lower flange in *compression*; that is, a *complete reversal of the ordinary condition of strain.*

For an excellent presentation of the above method, we refer the reader to *Iron Bridges and Roofs*, by W. C. Unwin. Pp. 128–140. The above method is there referred to as "*Prof. Clerk Maxwell's Method*," and as such is known and used in England.*

FIG. 7. (A)

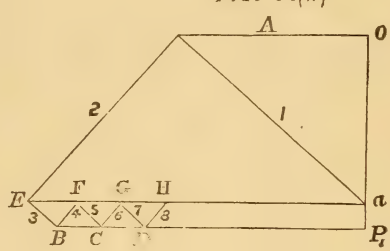
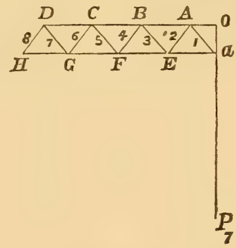


FIG. 7. (B)



BRIDGES.

12. For *bridges* the strains due to a *uniform* load are of course easily found. In most cases a *rolling load* can be managed also *without* making a separate diagram for each position of the load. Thus, if we

* Phil. Mag., April, 1864, and a Paper read before the British Association for the Advancement of Science, by Prof. Maxwell, in 1874.

For a thorough application of the method to Roof Trusses, see also an article by Skiesz, *Der Civilingenieur*, 20 Vol., *Viertes Heft*.

diagram the strains for the load at the first and last apex, the strains due to intermediate loads will be multiples or submultiples of these. A calculation for a simple Warren girder of small span, and a consideration of the reaction for each position of the load, will at once illustrate what is meant. [Compare Stoney, *Theory of Strains*. Pp. 99-111, Vol. I.]

Thus Stoney, in his *Theory of Strains*, Vol. I., p. 99, gives the girder represented in Fig. 7, span, 80 ft., depth of truss, 5 ft., 8 equal panels in upper flange, 7 in lower.

For the first weight of 10 tons, P_1, the strains are given by Fig. 7 (a) to a scale of 10 tons to an inch. We form first the *force polygon* by laying off from o 10 tons, to P_1. From the end of this line we lay off upwards the reaction at right abutment=$\frac{1}{8}$ of 10 tons, or 1.25 tons; and then the reaction at the left abutment=$\frac{7}{8}$ of 10 tons, back to o, thus closing the force polygon. [Note.—In *any* structure which holds in equilibrium outer forces, the force polygon must close. If it does not, there is no equilbrium, and *motion* ensues.] Commence with the reaction at a in the frame diagram, Fig. 7, because here we have a known reaction, oa (force polygon), and only *two* unknown strains to be determined. Drawing lines parallel to A and 1, we obtain the strains in A and 1. Then pass on to apex b. With the now known strain in 1, we can determine 2 and E.

Passing now to the next apex, we have A and 2 known, and *also the weight* P_1. Join therefore P_1 and E [Fig. 7 (a)] by lines parallel to B and 3. B and 3 are both in compression. We find diagonal 2 also in compression, and 1 tension. That is, *the diagonals under the weight are compressed*, as evidently should be the case. From 4 on we have tension and compression alternately.

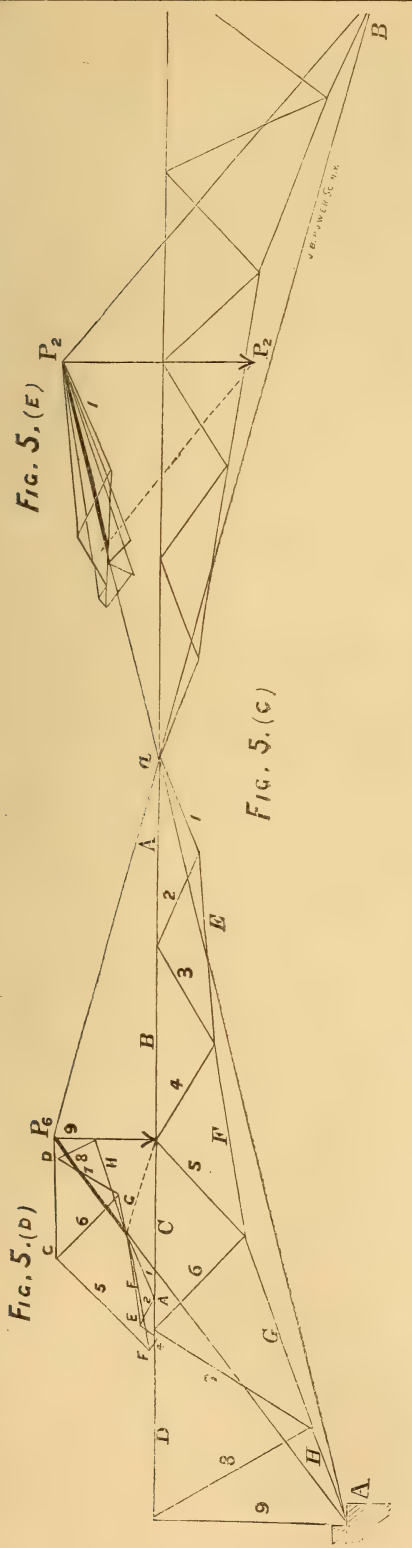
Fig 7 (b) gives the strains due to the *last* position of the load P_7. The strains in the diagonals are evidently all equal, and alternately tension and compression.

It is not necessary to construct more than these two diagrams. From these alone we can determine the strains for any intermediate weight. Thus scaling off the strains in Fig. 7 (a) and (b), we can tabulate them under P_1 and P_7, as shown by the table. Now the reaction at the left abutment due to P_6 is *twice* as great as that due to P_7. Hence the values in the column for P_6 will be twice as great; in the column for P_5 three times as great, and so on. For similar reasons the strain in 5 for P_2 will be twice that for P_1. In column P_2, then, from 5 down we multiply the strains in P_1 by 2. In P_3 from 7 down by 3. Thus we fill out the table of strains completely, and find the maximum tension and compression. A similar procedure will give the flanges.

DIAGONALS.	P_1	P_2	P_3	P_4	P_5	P_6	P_7	C	T
1..........	—12.4	—10.6	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	......	—49.6
2..........	+12.4	+10.6	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+49.6	......
3..........	+ 1.8	—10.6	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	+ 1.8	—37.2
4..........	— 1.8	+10.6	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+37.2	— 1.8
5..........	+ 1.8	+ 3.5	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	+ 5.3	—26.6
6..........	— 1.8	— 3.5	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+26.6	— 5.3
7..........	+ 1.8	+ 3.5	+ 5.3	— 7.1	— 5.3	— 3.5	— 1.8	+10.6	—17.7
8..........	— 1.8	— 3.5	— 5.3	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+17.7	—10.6

APPLICATION TO AN ARCH.

13. For a "braced arch" (Stoney, p. 136) as represented in Fig. 5 (c), the strains in every piece due to any load are in similar manner easily found by first finding the components of the load acting at the



abutments, and then proceeding as above. Thus for a load P_2, the left half of the arch is in equilibrium with the forces acting upon it; viz., a horizontal and a downward force at *a*, and a horizontal and an upward force at A. The resultant of the forces at *a* must then pass through, and be equal and opposite to the resultant at A. The resultant at the right abutment must pass through that abutment, and also the intersection of P_2 with A *a*. So for any other force, as P_6, we have simply to draw B *a* to intersection with P_6, and then P_6 A. We can now decompose P_6 or P_2 along the resultants through the abutments. Thus resolving P_2 along A *a* and P_2 B, we find the force acting at *a*. This force resolved into A and 1 gives the strains on these pieces both compressive. Passing then to the next apex, we obtain the strains in 2 and E. Then to the next, and we get 3 and B, compression and *tension* respectively, and so on, as shown by diagram, Fig. 5 (*e*), which, it will be seen at once, is similar to Fig. 5 (*a*), already obtained for the "semi-arch," except that the strain in A is less than for the semi-arch and compressive, while B *c* and D are in tension. The reason is obvious. At *a* [Fig. 5 (*c*)] the resultant lies *between* A and 1, and therefore causes compression in both, while it passes outside of the arch entirely, to the right of the apex for diagonals 3 and 4, and hence causes tension in B *c* and D. Fig. 5 (*d*) gives the strains due to P_6. Here the resultant or reaction at A is first found and resolved into *g* and H, and then we go through the frame as before. We see that 4 and 5 under the load are both compressed, that E and F are in tension and G and H, as also the entire upper chord, in compression. The work checks from the fact that the line closing the polygon formed by E and 2 should be exactly parallel to and give the strain in diagonal 1, or A and 1 should be in equilibrium with the resultant through *a* [see Fig 5 (*d*)].

In every case of the kind we first, then, have to draw the *frame diagram*. Then lay off the *force polygon* which should close. Finally we construct the *strain diagram*. The frame diagram should be taken to as large a scale as possible consistent with reasonable size, and the scale for the force and strain diagrams as *small* as possible, consistent with scaling off the strains to the requisite degree of accuracy. A small frame diagram does not give with the proper accuracy the relative positions and inclinations of the various pieces, so as to ensure the proper direction for the lines of the strain diagram. A slight deviation from parallelism causes sometimes considerable variation. Nevertheless with practice, care, and proper instruments the accuracy of the method is surprising: even in complicated structures, the variation resulting from performing the operation *twice* being inappreciable. Every symmetrical frame gives also a symmetrical strain diagram, and the accuracy of the work is tested at every point by this double symmetry, and finally by the end or last point of the second half, exactly coinciding with the last point of the first half. Thus in Fig. 6 (*a*), if we had but one system of triangulation carried through the frame, the strain diagram for the right half would be precisely similar and symmetrical to that already found for the first, and the end of the last line would fall, or should fall, *precisely* upon the point *b* of the first. If it does not, and the error is too great to be disregarded, by checking corresponding points in each half, we can find the point where the error was committed. In any case *errors do not accumulate.* Thus, armed with straight edge, scale, triangle, and dividers, we can attack and solve the most intricate problems, without calculation or tables, with ease, accuracy, and great saving of time.

METHOD OF SECTIONS.

14. The results obtained by the above method are best checked in general by Ritter's "method of sections," [*Dach und Brucken Constructionen*]. This consists in supposing the structure divided by a section cutting only *three* pieces. We can then take the intersection of *two* of these pieces as a centre of moments, and the sum (algebraic) of the moments of all the exterior forces, such as reaction, loads, etc., upon one of the portions into which the structure is divided by the section, with reference to this centre of moments, must be balanced by the moment of the strain in the third piece, with reference to this same point. Thus in Fig. 6., Pl. 2., required the strain in D. Take a section through D 7 and H (right half of Fig.) and let *a* be the centre of moments. The moments of the strains in 7 and H are of course zero, since these pieces pass through *a*. The moment of the strain in D with reference to *a* must then be balanced by the sum of the moments of the outer forces acting upon the portion to the left (or right) of the section.

Thus, strain in D multiplied by its lever arm with respect to *a*, is equal to moment of reaction at A, minus sum of the moments of loads between A and *a*, all with reference to *a*. If we take rotation in the direction of the hands of a watch as *positive*, and we find the moment of strain in D *negative*, it shows negative rotation about *a*, and the strain in D to resist this rotation must act *away* from *b*, or be tensile. If the resultant rotation of the outer forces is on the other hand positive, the strain in D must act *toward b*, and D is therefore compressed.

This method of calculation, it will be observed, is both simple and general. It can be applied to any structure, when the outer forces are completely known, and only three pieces are cut by the ideal section.

15. It is unnecessary to give further applications of our graphical method. The reader can easily apply it for himself to the "bowstring girder," bent crane, etc., and satisfy himself as to its accuracy, and the ease with which the desired results are obtained.

Enough has been said to indicate the many important applications which even at the very commencement of our development of the graphical method we are enabled to make, and here we shall close our discussion of forces lying in the same plane and having a common point of application. As we pass on to forces having *different* points of application, we shall have occasion to develop new principles and relations not less fruitful and useful in their practical results.

TELEGRAPH cables have been laid during the year between Jamaica and Porto Rico, and another short West Indian section, also between Constantinople and Odessa, between Zante and Otranto, and between Barcelona and Marseilles. The amount of mileage added to the submarine system has been very great.

MECHANICAL ENGINEERING.*

From "Engineering."

What is the profession of a mechanical engineer? What is meant by "engineering?" That question was put, and it was answered many years ago, by a man whose works on engineering subjects are text-books even at the present day. I mean by Tredgold, who for the Institution of Civil Engineers gave this definition, that "engineering is the art of directing the great sources of power in nature for the use and convenience of man." Accepting this definition, let us see whether mechanical engineers have to any and to what extent carried out and fulfilled the obligations they took upon themselves when they became members of a profession which exercises such an art. I believe in answering that question we may, without boasting, say that mechanical engineers have, to a very large extent, fulfilled the obligations imposed on them by their profession. Let us review, as briefly as possible—so briefly indeed as to make the review little more than a list of the names of the subjects we shall notice—what has been done by the mechanical engineer. Happily for my purpose, we may confine our thoughts to a limited range of time, for in our profession, unlike that of the sculptor, the painter, or the architect, we have not to go back to past ages to find its triumphs—in fact, so little is to be gleaned from antiquity that I will not be tempted even by the name of Archimedes to advert to ancient engineering, but I will at once limit myself to a time so recent that it shall not carry us back to a date anterior to the lives of some of our present members, not anterior indeed to the lives of two of our past Presidents—Sir William Fairbairn and Mr. Robert Napier—both gentlemen who happily have contributed their fair share, and more than their fair share, to engineering progress. I will even take a shorter period than that included in the lives of our venerable friends, and will ask you to bear with me no longer than while I mention some few of the leading mechanical matters belonging to the nineteenth century only. To commence with that which is still the masterpiece of mechanical engineering, the steam-engine, I cannot say that it has been invented within this period, because doubtless it existed some little time before, not only for pumping purposes, but also to a very small extent for manufacturing purposes; but I may safely say that its practical application to these latter purposes has taken place within this century. Steam navigation is of even more recent origin; while the beginning of railways is, to men of my age, as it were a thing of yesterday; and the establishment of the electric telegraph is within the recollection of all but our youngest members. The science of sanitary engineering, although claimed, and perhaps properly claimed, by the civil engineer, depends so largely, especially in those parts of it which relate to the distribution of water, and to warming and ventilation, upon the aid of the mechanical engineer for pumping engines and other purposes, that it demands to be mentioned among the matters connected with our profession, as does also, which is almost a branch of sanitary engineering, the distribution of light by those gas works which, from first to last, are the product of the mechanical engineer's skill. The supplying of water by the aid of the mechanical engineer dates, it is true, from long before the commencement of this century, but the steps that have been made towards the perfecting of such a supply are so great that the matter may almost be treated as if it were entirely within the period of which I am speaking; while the practical manufacture and transmission, though not the very first production of gas, are quite within that period; as is also (when considered as a science) the getting rid of our sewage. But to the mechanical engineer we owe not only the laying on of light, as that word is ordinarily understood, but we owe to him the greatest improvements in laying on light to the mind, for we owe to him the steam printing-press, a machine which has developed from the early inventions of the father of one of our oldest and most distinguished

*Inaugural address before the Institution of Mechanical Engineers by the President, F. J. Bramwell.

members, one of the founders of this institution, Mr. Cowper, to the admirable machine by which *The Times* newspaper has for some years past been printed; and if the mechanical engineer had done no more than invent the steam printing-press, he would be justly entitled to the gratitude of the whole world. But the steam printing-press would have been a useless implement if paper had not been forthcoming in proper quantity and in proper form. Hand-made paper, it is true, might have sufficed, and did suffice for earlier constructions of printing machines; but the machine-made paper, another invention of the period under consideration, is, as you all know, an indispensable adjunct of *The Times* printing machine, as one of the great excellencies of that machine is the dispensing with the intermittent feed of separate sheets, and the substituting for it the continuous feed of a continuous sheet of miles in length. Within this century—in fact, within the last few years—we have had the mechanical engineer largely aiding the civil engineer. I have said "aiding," but, in one instance at least, "aiding" is far too weak a term to apply to the position of the mechanical engineer in relation to the civil engineer, for it would not be too much to say that, by the production of the locomotive engine, the mechanical engineer "created" the civil engineer, so far as that important branch of the civil engineer's business is concerned, the making of railways. In numerous other matters we have had the mechanical engineer really "aiding" the civil engineer, and especially in those appliances which have rendered practicable the performance of subaqueous works, such as our forefathers never would have dreamt of as possible. We have had him aiding the miner and the collier; and we have had him, by improved machinery, aiding the metallurgist; and upon this head it will suffice to mention the names of Neilson, Bessemer, Siemens, and Nasmyth, famous for their respective improvements in furnaces, in decarbonizing iron, and in treating the produce of the furnace, when that produce is malleable, by the steam hammer; and were it needful to prove to you the vast scope of the mechanical engineer's profession, I might do it by taking in contrast to such an improvement as that of the huge steam hammer, the delicate mechanical inventions which have been applied to the production of the finest thread, and to the use of that thread in the sewing machine. In fact, the talent of the mechanical engineer may be likened to the trunk of the elephant, which, as we all know, has been said to be competent to "root up a tree or to pick up a pin." The matters I have as yet noticed have all been connected with peaceful art, but the mechanical engineer has not confined himself to those alone, for we have had men, members of our body, past presidents of this institution—Armstrong and Whitworth—devote their powerful minds to devising weapons to enable us to defend ourselves against aggression. I will not detain you by more instances. I cease from further enumeration, not because the subject is exhausted, for that is well-nigh impossible, but because I am sure I have said enough to show you that, within the present century, the profession of mechanical engineering has originated matters of the highest value. But, if the subject of the inventions of the mechanical engineer is all but inexhaustible, that of the matters to which those inventions are applicable is absolutely so, and thus, as it is impossible to make any summary of them, I will, in sheer despair at their multitude, content myself with a bare recital of a few only of the benefits that we receive from those applications, and I will begin with mental benefits, benefits in the interchange of thought, and will only take one branch of them, that of the publication and transmission of news. Let us look how this is accomplished. The railway or the steamboat brings detailed intelligence, the essence of which, however, has been brought before by the electric telegraph. The news is put into type, but even this now is done by the aid of machinery, which arranges the separate loose types in their proper order. From these is taken a paper mould, in which castings of stereotype metal are obtained in quick succession, and in the course of a few minutes, by the aid of the planing machine and the lathe, these castings are fitted into the steam printing presses I have mentioned, and thus in less than an hour after the completion of the "composition," four or five presses may be at work, printing each its 10,000 copies an hour. No sooner is the printing done than the railway again comes into play, to distribute the papers through the country, and the telegraph also comes into play to furnish copious extracts of all the principal matter to the newspapers throughout the provinces.

To the railway, to steam navigation, and to the telegraph we owe the breaking down of the barriers called space and time, which separated nations and individuals, and to these inventions, therefore, we owe the enormous extension of commerce and of personal communication. By the aid of the mechanical engineer we obtain our fuel, for not only is he required in keeping our mines free from water, in raising the fuel to the surface, and in maintaining efficient ventilation, but to him we owe such machines as those of Mr. Firth and others, by which the most trying part of the labor of getting coal is transferred from sensitive humanity to inert iron and steel. To the mechanical engineer we owe, by the aid of the fuel so obtained, the mastery over all the intractable metals, whether as in the case of cast iron extracted from the ore in the furnace with its heated blast, and delivered in the form of "pigs;" whether converted from that form by streams of air at high pressure, as by Bessemer, or whether obtained from the ore at once in the form of steel or iron as by Siemens. Having got the metal separated from the ore, to the mechanical engineer we owe its shaping into all the desired forms, whether for rails, ships, guns, engines, or for use in our dwellings, and as regards the other materials we employ in those dwellings, the inventions of the mechanical engineer dress the stone, make the bricks, saw and plane the timber, and mould it into gracious forms. As for our clothing, from the very coarsest fabric to the most delicate lace, the hand of the mechanical engineer has been engaged on every stage of the manufacture, and the materials thus made are united to form garments by the now all but universal sewing machine, a machine which in itself is a study, and has varieties so great as to enable it to cope with the finest fabric or even with the thick and obdurate leather forming the sole of the stoutest boot; but not only do we owe to the mechanical engineer the preparation of our dwellings and of our clothing, but we owe to him the very greatest aid in the production of our food; for it is with his assistance that we till the ground, that we sow it, that we cut the crop, thrash out the grain, and convert the product into bread—in short, it is no exaggeration to say that there is no one want, one comfort, or even one luxury that is not either directly or indirectly dependent on the mechanical engineer for its production, or for the bringing of it within our reach. I have thus, in as condensed a form as possible, brought to your notice some few things that mechanical engineers have done, and some other things which result from the use of their inventions; and I think that a consideration of these must make us all proud of our profession. I know that pride is commonly held to be bad, or if not absolutely bad to be dangerous; but there is to my mind the greatest possible difference between individual pride and pride in one's profession. In the case of individuals we must all appreciate the value of modesty, and it seems to me that that modesty may, in fact must, be a result of the very pride we take in our profession; for when we reflect upon it is it not impossible for any one of us to refrain from asking himself, "What have I done to advance our profession?" The very best of us must answer, "I have done but little;" and most of us must answer, "I have done nothing;" and thus it is that, as I have said, a consideration of the dignity and importance of our profession is the means of all others to make us as individuals modest, dissatisfied with ourselves, desirous of doing better. With respect to the desire of doing better I am aware one is apt to say, "What chance have I? What is there great that is left to be done? Those men who have gone before have anticipated me; the grand substantive inventions and improvements have been made by them; they have reaped the harvest, and there is nothing but the corners of the field for me to glean." But this feeling, although natural, is one that should not be yielded to. Depend upon it, such a feeling is the suggestion of our evil genius; for although I cannot indicate to you what will be the grand inventions that will be made in the course of the next fifty years (for if I could I should go a long way towards being a great inventor myself), nevertheless we know that within the next fifty years great inventions will be made, and we are sure that any one then looking back on the condition of things in engineering science at the present time, and comparing it with that which he will then know of, will wonder how it was that the men of this day failed to make many a grand discovery which at that time to him will be as familiar as the steamboat or the locomotive is to us. But although I am necessarily unable to predict to you what will be the great substantive inventions of the future, it is within my power to remind you of many useful directions of improvement. First, the great question of the preservation of our fuel, which, at the risk of impropriety in repeating myself, I must call the very "breath of the nostrils" of our principal machine the steam engine. About 120 millions of tons of this most valuable substance are raised to the surface in our small island every year. Such a quantity as this fairly staggers the imagination; and it seems incredible that the deposits below this minute portion of Europe can long hold out against such an annual attack, and one cannot help asking oneself, Is this quantity honestly used—is it honestly got? By that primary question "Is it honestly got?" I do not mean "honestly" in the dry legal sense—that is to say, I do not mean that any law is infringed, or that any person is doing wrongfully so as to be amenable to our Courts of Justice; but I mean is it got honestly as between man and man, as between ourselves and those who are to come after us? Do we not work coal pits with no other object than that of obtaining the utmost present profit out of them? do we not thereby leave behind the less immediately valuable coal, and, leaving it unassociated with that which is more profitable, render it all but impossible for those who come after us to get, except at too great a cost? Whereas we might by a small present sacrifice extract a great deal of that which now we think not worth obtaining. And cannot the skill of the mechanical engineer come in here to work seams which manual labor is not able to touch without the reduction of the present gain? I will say no more on the subject of "getting" coal, as I do not wish to trench upon the especial province of our brethren the North of England mining engineers, who we are happy to know are holding their meeting in this town contemporaneously with ourselves. Coal is one of "the sources of power in nature." It may be considered (as our past President, Dr. Siemens, explained last year in his lecture at Bradford) the representation of the stored-up heat of the sun; and it is part of our art to direct that source of power for the use and convenience of man, and we have so directed it by employing it in the steam engine. But have we not in consequence of the facility of its application been tempted to neglect other sources of power in nature? Have we and do we sufficiently utilize the waterfall, the tidal wave, and the force of the wind? and with respect to the employment of these forces we should remember that we are enabled to utilize water power in a way which to the engineers of the last century was unknown. They availed themselves of the waterfall—indeed, it was their chief source of motive power; but they were compelled to place their manufactories close to the falls. We, however, know that it is perfectly possible to transmit (at some cost by loss of power, it is true, but not at a prohibitory cost) power to very long distances. The transmission, so far as invention has at present gone, may be made by exhaustion of air, as practised by Hague 40 years ago, by the compression of air, by rocking rods, by swift running wire ropes, and by the employment of water under pressure as practised by Sir William Armstrong. But do we resort to all those facilities for transmitting power from a distance? Do we resort to any large extent to sources of power in nature other than coal? Is it not the fact that mechanical invention has gone back in these matters rather than forward? and do we utilize that primary source of power, the heat of the sun, the current heat from year to year, by making the most of barren hillsides, as, it seems to me, we might do by planting quick-growing trees, which, fostered and matured by the sun, would yield large quantities of wood to be used as fuel for domestic purposes? Are we estimating at their full value the deposits of peat? and are we not tempted to pass by this large store of fuel because its use is attended with difficulties? In those cases where coal must be used for power, has it not to be admitted that in far too many instances it is recklessly, wickedly employed; that the engines are, in their design and construction, disgraceful; and that a consumption obtains equal to four, five, or even ten times that which would suffice with proper engineering care? In the same way when we employ coal for heating purposes only, such purposes as metallurgical operations demand, is it not in too many instances used in the grossest manner? How much of the fuel goes up the chimneys of our furnaces unconsumed in the form of visible carbon, or in the worse, because less detectable, form of invisible carbonic oxide? How much of the heat of the coal escapes uselessly into the air in jets of flame, which in the night time throw their light around for miles? It cannot be doubted that we have been and still are, although I believe and trust we are improving, most cruelly wasteful, and, as I have said, wickedly wasteful. It pains me when I hear a man talk of "only a bit of coal;" he cannot think of what he is saying. "Only a bit of coal!" Only a bit of that which might have helped to gladden some man's fireside. "Only a bit of coal!" Only a bit of that which if not wasted but properly used might have helped and might have succeeded in saving some noble vessel with all its brave crew from perishing on a lee shore. "Only a bit of coal!" Only that which might have assisted in wringing the bright metal from the sullen dross with which it had been associated for countless ages. "Only a bit of coal!" Only that which has been got at the peril of men's lives, and not at the mere peril but at the actual cost of men's lives, for ten men die violent deaths for every million of tons raised. "Only a bit of coal!" Only part of the store which the Almighty had buried in the recesses of the earth to be treasured up there for the use of generation after generation. It really is grievous to hear men talk slightingly of "only a bit of coal;" and I think it becomes us mechanical engineers, by precept, practice, and example, to do all that lies in our power to cause persons to respect and to understand the value of that which they have but too long lightly treated and grossly abused. I feel I owe you apology, or at least explanation, for the remarks which I have made upon the saving of coal, because remarks of this character have of late years been made by others than myself, and I personally have made them before another scientific meeting; but the truth is that my mind is so forcibly impressed with the importance of the question that I hardly know how to refrain from alluding to it, especially when I have the opportunity, as I have now, of addressing a body of gentlemen who of all others are those who can do most towards curing the evils of which I have complained; and further, in excuse of my having to some extent repeated myself on this subject, I will ask you to remember that however important a reform may be, it is not brought about by a single statement, although the facts contained in that statement may be absolutely incontrovertible, but that improvement and reform need for their carrying out repetition and reiteration of the circumstances which render such reforms necessary. I have occupied so much time in this question of the improvements which might be effected in relation to the getting and use of coal, that I will merely, in a few words, allude to some other directions of improvement within the scope of our profession. One of these is the substitution of mechanical force for that of manual labor in all cases where the labor is that which though rendered by man does not demand the exercise of human intelligence—mere brute labor—as when men are employed to raise weights. We are, however, so used to this that we are not shocked at the sight of a man turning an ordinary crane; but when, as in years gone by, one might have seen in the London Docks, and when, as I have recently seen on the Continent, men are performing the same work by working inside a tread-wheel and causing it to turn, we involuntarily think of the turnspit, and are compelled to admit that this is mere brutal labor—labor indeed to which we put our convicts as a punishment; and one feels that a man like Sir William Armstrong, who by his invention transmits the force of a central engine in some large dock, or on a quay side, to all the cranes and hoists within its area, is a benefactor to the human race, because, hard as it may be at the time of the change, he has by his invention rendered it impossible for a man to earn his bread by the exertion of muscular strength without the exercise of intelligence, and thereby he is really doing his part in the progress of humanity. There is another class of labor, which, although it demands high skill, and therefore does not come within the category of brutal labor, but is far from it, yet on account of its fatiguing and exhausting nature one would wish to see superseded. I allude to such labor as that of the hewer of coal, and to such labor as that of the puddler. In these two instances, however, we are happy to know that we are far on the track of substituting mechanical appliances for the arm of the workman. Then there are open to our members improvements in the comfort and in the safety of our travelling by land or by sea. I trust I am not too sanguine when I say that I hope for greater speed in both those modes of journeying, for greater comfort, even in the mastery of sea-sickness, and for greater safety by better signals and by improved modes of communication between those on the train and those in the station or signal houses, and by better means of rapidly and safely arresting the speeds of trains. Again, I think one may look for more satisfactory modes of uniting materials. In the constructive arts, there is no doubt that the uniting of the materials is as supremely an important part as in the construction of a sentence is the verb; in fact, it is a mere truism to say that without the means of uniting, construction is impossible, unless construction were confined to that of those former ages into which I have said I would not travel, where it meant little more than placing one stone upon another. It is, I must say, a disgrace to mechanical engineering that we cannot unite such materials as iron or steel without the barbarous expedient of cutting away a large percentage of their strength by making holes to admit of the insertion of bolts and rivets, and we ought to be able to devise means of union by welding, which should almost entirely supersede our present very primitive mode of procedure. The foregoing are all matters for ourselves alone, but there are others where either alone or in conjunction with the chemist there is obvious room for improvement; such are the making use of the so-called, and in most cases most improperly so-called, "waste products" of our various manufactures, the getting rid of gases and fumes deleterious to health, the obtaining of purer water in our dwellings, and the saving of metal in metallurgical operations, for too surely do we now needlessly waste, in many of those operations, the very metal which should be their product. I will not continue further these suggestions, but will only repeat that, in the absence even of great substantive discoveries, such improvement affords wide scope for the mechanical engineer, and therefore the prospect of those who are to follow us is by no means a gloomy one, and it must be remembered that those men will come to the subject with advantages which very few of their predecessors possessed. Most of us had to rely on our innate love of the profession and our mother wit for all that we have done. Technical education in our day was a thing unknown, and scientific education fell to the lot of but few; but those who succeed us have, or if they have not it is their own fault, the advantages which were denied to us of scientific training, and therefore, as I have said, they not only have a wide field before them, but there is good reason to believe that by their training they have every facility for cultivating it. While on this subject, I cannot refrain from saying that the success of the men of the past generation, in the absence of special training, was, I believe, in a large measure due to this—that they became engineers literally because they could not help it; that the taste for it was born with them, and that their very natures compelled them to follow that taste, and when men enter the profession from such causes as these it is not surprising that they succeed, even in the absence of extraneous aid. But now-a-days it is too commonly the fact, I am afraid, that a man becomes a mechanical engineer as he might become a wine merchant or a stockbroker, because his father wants him to earn his livelihood in some way, or because he has got capital at command, and not because he has the real love of the profession in him. Such a man may succeed, but if he do he will do it as a mere manufacturer, about whom and about the subdivision of our profession I now wish, in conclusion, to say a few words, as they are both subjects which may prove sources of danger to the advancement of that profession. Forty years ago the business of a mechanical engineer was general. The man who made a marine engine, made a locomotive, made mill work, and made land engines, but within the last few years the business of the mechanical engineer has divided itself into distinct branches, so that the locomotive builder is little more than a locomotive builder, or the marine engineer than a marine engineer. I presume such division is the almost inevitable result of the growth of an industry, and so long as the productions of that industry are not intimately connected with science, separation is probably a thing to be desired as cheapening the article produced; but in the business of the mechanical engineer, closely allied as that is to science, the separation of his industry into branches appears to me to be dangerous. It narrows his opportunities of gaining knowledge in his profession, and he is in danger of becoming the mere manufacturer. But the division into branches to which I have alluded must, I am afraid, continue. It is most desirable, however, that those who, by their commercial practice, are devoting themselves to one section alone of the mechanical engineer's business should, as a matter of duty, keep themselves thoroughly acquainted with the state of all the other sections of our profession, and with the improvements that are being made in those sections; and I know of no better means of so doing than by their lending their heartiest co-operation to the advancement of our institution, by communicating to it all that is useful that comes within their knowledge, and by assiduous attendance for the purpose of testing, by discussion, the value of that which is brought before the Institution, and of adding by their remarks to the information imparted in the papers; but to those of our brethren who are so absorbed in their business as manufacturers that they care not to devote time to advancement of the general scientific position of the profession, I will still say that they may uphold its usefulness, and even its dignity, by the excellence of the products of their manufacture, and let us trust that competition, however keen it may be, and whether between the natives of these islands, or whether between them and the foreign manufacturers, may never drive our members to seek commercial success at the cost of the excellence of their work, but that competition may have the opposite effect, and may make them feel that in a high reputation lies the best hope of excelling and of gain, and thus competition itself may be the means of causing them to discharge their duty to the profession of which they are members. I fear that in this address there are to be found occasionally the tones of censure mingled with those of exhortation, but if this be so, it has arisen from my desire to bring before you that which I believe to be the truth. It is well that some one should bring the truth before us from time to time, and that in this instance it has been done by me is the result of your own act, because it is you who have selected me as President of the Institution. This address has grown to a greater length than I had intended, such a length, indeed, as to make me feel that I have incurred the risk of wearying you and of making you impatient by keeping you from the regular business of the meeting; but I shall not have incurred that risk in vain, if I have succeeded in that which I set myself to do at the outset—namely, the withdrawal of your minds for a short time from individual interests and pursuits, to the consideration of the broad features and aims of our noble profession; and if in any way I have stirred you up to resolve to do all in your power to advance that profession to which we are all, I trust, proud to belong—the profession of the mechanical engineer.

New White Alloys.—White metallic compounds are frequently patented, and seem for some reason to be more in demand than those of any other color.

The following, invented by an English metallurgist, Mr. Parkes, of Gravelly Hill, is the latest. It is a silver-like alloy which can be rolled and worked when red-hot from copper, manganese, zinc, and sometimes nickel. A silver-like alloy which will also work at a red heat is also produced from nickel, copper, and zinc. When the silver-like alloy is not required to work at a red heat, it may be produced from copper, manganese, iron, and zinc. A solder for these compounds is produced from copper, manganese, and silver.—*Mining Journal.*

THE CONDITION IN WHICH SILICON EXISTS IN PIG IRON.

By MR. E. HANDFIELD MORTON.

From "Journal of Iron and Steel Institute."

I WAS induced to make a few experiments upon the subject of this paper, by noticing that silica was obtained in the insoluble residue when pig iron containing a large quantity of silicon was dissolved by dilute sulphuric acid *in vacuo* instead of silicon, which might have been expected as the result of the decomposition of the pig iron under these conditions.

This fact appeared to clearly point out that the theory of silicon being intimately mixed with pig iron was untenable, at least as regards this particular pig, which was a No. 1 Bessemer iron, containing 4.612 per cent. of silicon, and was, therefore, not at all unlikely to contain silicon in admixture, if that element ever occurred in pig iron in such a condition.

As far as I am aware, no experiments have been made with the object of proving that silicon exists in a state of combination in pig iron, although I believe it is the generally received opinion that such is the case. I therefore made a considerable number of experiments with the view of ascertaining how far this conclusion was correct.

Weighed quantities of the Bessemer pig iron were placed in sealed tubes with Nordhausen sulphuric acid, in atmospheres of carbon dioxide and hydrogen, and also *in vacuo;* the tubes were then heated in an air bath by two Bunsen burners for twenty-four hours, but in every case the silicon contained in the pig iron had been converted into silica, and a small quantity of sulphur dioxide formed in the tube, which occasioned sufficient pressure to blow the top off the tube when cracked with a file. On examining the insoluble residue from these experiments under the microscope, perfectly transparent crystals of silica were observed interspersed with opaque pieces of the same substance. When these insoluble residues were treated with hydrofluoric acid, complete solution was effected.

The next attempt to isolate the silicon in this pig iron was made by heating weighed quantities of the iron with an excess of pure iodine in sealed tubes, all air being first displaced by carbon dioxide, the same heating arrangement being used as in the sulphuric acid experiments. At the end of twenty-four hours, all iodine vapor having disappeared, one of the tubes was opened and the contents analyzed, wlth the following results:

Iodine	76.432	per cent.
Iron	20.013	"
Silica	1.709	"
Carbon	0.759	"
	98.913	per cent.

Directly the tube was cracked, the pressure of gas blew the top off. The contents consisted of dull red lumps, the whole of the iron having been converted into the ferrous iodide, as the above figures correspond to the formula FeI_2. There can be little doubt but that the silica which was formed in this experiment was due to a slight decomposition of the carbon dioxide with which the tube was filled; the greatest part of the silicon having been converted, in all probability, into an iodine compound. For, although iodine vapor is without action upon silicon under ordinary conditions, it is highly probably that when silicon in the nascent state is presented to iodine vapor, a compound of iodine and silicon may be formed. These results were confirmed by several other similar experiments. This pig iron was also carefully tested for graphitoidal silicon, by treating the iron with hydrofluoric acid; the insoluble residue was filtered off and ignited to get rid of carbon, when a mere trace of a dark powder remained, which proved to be iron.

From these results, it may fairly be concluded that the silicon contained in pig iron does not exist in a state of mechanical mixture, but exists combined with a portion of the iron as a silicide of iron, in the same manner that carbon exists as a carbide of iron, only differing from carbon in so far that it does not exist in a graphitoidal form in pig iron. If the pig iron used had contained any uncombined silicon, it would have been found in the insoluble residue from the experiments with Nordhausen sulphuric acid and hydrofluoric acid, as it is insoluble in even the latter acid, after having been strongly heated, and as any uncombined silicon must have been heated intensely in the blast furnace, there can be little doubt that as a rule, pig iron does not contain any uncombined silicon.

I then made the following experiments in order to ascertain whether or not the hypothesis of the combination of the silicon with the iron was correct: 0.1694 grm. of the Bessemer pig iron was placed in a platinum boat, which was then introduced into a porcelain tube. A current of carbon dioxide was passed through the tube to displace the air, after which pure dry hydrogen was passed through until all the carbon dioxide had been driven out. The portion of the tube which contained the boat was then heated for five hours to a very bright red heat in a Fletcher's gas furnace, the current of hydrogen being maintained until the tube was cold. The boat was then withdrawn and weighed, when it was found that a loss in weight of 0.004 grm. had taken place. The gas, as it left the apparatus, was passed through a wash bottle containing a weak solution of pure caustic potash (prepared from alcohol); at the end of the experiment, this solution was made acid, and with pure hydrochloric acid evaporated to dryness and ignited, when an insoluble residue of silica was obtained, which gave 0.344 per cent. of silicon on estimation. The iron in the boat (which after its withdrawal from the tube showed no sign of oxidation) was analyzed with the following results:

Iron	92.018	per cent.
Silicon	4.130	"
Graph. Carbon	1.622	"

For comparison with the above analysis, is subjoined that of the pig iron used:

Iron (by difference)	92.375	per cent.
Graph. Carbon	2.800	"
Silicon	4.612	"
Phosphorus	0.110	"
Sulphur	0.103	"
	100.000	

This shows that there is a loss of silicon to the amount of 0.482 per cent.

The above experiment was repeated several times with almost identical results. It will be observed that the amount of silicon found in the caustic potash solution very nearly corresponds with the loss of silicon sustained by the iron operated upon. Thus, 4.130 per cent. + 0.344 per cent. = 4.474 per cent. silicon, instead of 4.612 per cent.; the difference being 0.138 per cent.

In the event of the silicon being in combination with the iron, I calculated in the above experiment upon the reducing power of hydrogen being able to decompose the silicide of iron, with the formation of silicuretted hydrogen, which would be decomposed by the caustic potash solution; and this appears to have taken place. Possibly the temperature of molten iron is required to effect the decomposition of the whole of the silicide of iron, or else the attraction of iron for silicon is so strong as to defy, in a great measure, the reducing power of hydrogen. This last hypothesis is by no means improbable, when the high temperature of molten iron is taken into account, for the fact is generally admitted that chemical affinities are frequently reversed in the presence of an intense heat.

A sample of white pig iron containing a large quantity of silicon having been given to me, I thought it might be interesting to ascertain whether hydrogen had the same effect upon the silicon contained in the white iron as it had upon that found in the Bessemer iron used in the preceding experiments. 0.1420 grms. of the white iron was heated in the same apparatus, and under the same conditions as existed in the previous tests, for six hours at nearly a white heat. When cold, the iron was analyzed, as was also the caustic potash solution, with the following results:

Iron	89.201	per cent.
Graph. Carbon	1.060	"
Silicon	4.287	"

Caustic potash solution: silicon=0.494 per cent.

The composition of the white iron used is shown by the annexed analysis:

Iron	90.000	per cent.
Grap. carbon	2.975	"
Silicon	4.704	"
Undetermined	2.321	"
	100.000	per cent.

The amount of silicon found in the caustic potash solution is 0.077 per cent.

more than is required to account for the loss of silicon sustained by the irons used, which amount may be said to be within the limits of error of experiment.

The following table shows the amounts of loss of silicon sustained by the iron used in these experiments, and also the quantities of silicon found in the potash solutions:

	Loss of Silicon.	Silicon found in Potash solution.
Bessemer pig iron	=0.482 per cent.	0.344 per cent.
White "	=0.417 "	0.494 "

On comparing the results obtained from the two kinds of iron used, it is evident that the effect of hydrogen upon the silicide of iron is identically the same in both cases, and this has led me to believe that the amount of silicon lost by the iron in each case is due to the silicide of iron containing an atom of non-saturated silicon, or in other words, that the silicide of iron was super-saturated, and consequently the non-saturated atom of silicon united with the hydrogen, leaving a lower silicide of iron undecomposed. It is my intention to endeavor to prepare and isolate definite silicides of iron. If the experiments should prove successful, the chemical composition of the silicides may throw some light upon the forms of combination of silicon in the various kinds of pig iron now in use.

In conclusion, it may be fairly considered from these experiments that silicon in pig iron is not contained in a state of mechanical mixture (except perhaps under peculiar circumstances), but as a chemical compound of iron and silicon, dissolved, so to speak, in the pig.

IRON PIERS.

From "The Engineer."

Of all braced structures, an iron pier, built according to the principles of modern engineering, depends more than any other for its security and durability upon the manner in which the bracing of the component parts is designed and executed. As the type for an illustration, we may select a pier consisting of three principal parts, viz., iron piles, driven or screwed; iron superstructure, solid or open; and timber platform or decking. If we restrict our selection still further, and make the foundations cast iron hollow screw piles, the superstructure lattice girders, and the decking, narrow planks close jointed, we shall probably arrive at the description of pier possessing the minimum amount of inherent rigidity, demanding at the same time the maximum amount of extraneous stiffening and bracing, and yet capable of being erected with all due regard to both scientific designing and permanent economy. A pier built in the manner described may fill in various ways; thus the holding powers of the piles may be sufficient; they may be bodily uprooted, and the whole superincumbent structure come to the ground, or fall into the water, as the case may be, and the same result might also be produced by the scouring out of the ground at and around the piles. At home this disturbing cause is not likely to occur, but it is by no means an uncommon event in India and other foreign countries, where rivers have been known to scour out their beds to a depth of nearly 40 ft. in a single night. In ordinary cases, the precautions used against the uprooting of the piles are a screw blade of sufficient diameter, the proper pitch of screw, and a penetration into the bearing stratum to the extent required. The first two of these conditions are generally complied with, but the third, from motives of false economy, is very frequently violated. Directors of companies are very prone to cut down estimates so closely, that an engineer will sometimes cheapen a design in the simplest manner possible. This, in the case of an iron pier, is readily effected by diminishing the depth to which the piles are to be screwed, without in the least degree affecting the rest of the structure. Nothing can be more injudicious or short-sighted. An engineer had better fine down his material, use second-rate timber, and employ any alternative to bring, if possible, the cost of the structure within the prescribed limits, than diminish by a single inch the holding power required for the piles. Damage done to the superstructure can be repaired with comparative facility, but if a few piles happen to give way, the whole structure is in jeopardy.

While all the component parts of an iron pier should present as little surface as possible to the action of the waves, yet a certain amount of strength, and consequently of material, is indispensable. But it is with regard to the decking that especial precautions must be taken to avoid the force of the sea. Obviously, if the upward pressure of the water were once brought to bear upon the under surface of the deck, nothing could prevent it being lifted off the girders, or as it is commonly called, blown up. We do not suppose that any engineer would arrange the levels of a pier in such a manner that this catastrophe would happen under ordinary or even extraordinary tides. But the question of storms must be taken in consideration, and in connection therewith another point must be noticed. In order to blow up the deck it is not necessary that the waves should actually come into contact with its under surface, especially if the breadth of the pier be upwards of 40 ft. The rising of the sea in a heavy storm, together with the violence of the wind, may so compress the air in the confined space between the surface of the water and the under-side of the deck, as to produce precisely the same result as if the waves themselves rose to the deck level. It might be imagined that a remedy against this contingency might be easily provided by the simple expedient of laying the deck boards with the space of about an inch or thereabouts between them. Under certain circumstances there can be no doubt that this precaution would prove advantageous, but it is quite a mistake to suppose that it would prevent the blowing up of the deck in the event of the waves acting during a severe storm in the manner already described. The suddenness of the shock and the velocity of its action would easily start or break the planks. Besides, small spaces between deck boards after a time usually become more or less choked up with dirt and grit, so that even the partial advantage derived from their adoption is considerably diminished. We are not to be understood as condemning the practice of employing open decking. On the contrary, in certain cases it should always be adopted. When a pier is erected solely for the purpose of trade and commerce, and for the loading and unloading of goods, it should always be used. What we intend to imply is, that its advantages as a means of increasing the security of the structure are frequently much overrated; in consequence other necessary precautions are neglected or treated as of secondary importance. The decks of piers intended to serve as resorts for fashionable promenade, such as those at Brighton, Hastings, and elsewhere, are best closely laid and well caulked. Apart from other considerations, open decking should be employed whenever practicable for reasons of economy. Not merely are fewer squares of planking required, but the expense of caulking is avoided, which is a serious item in the total cost.

The proper method for obviating the dangerous tendency of the waves to blow up the deck of a pier is to place it at sufficient height above high-water mark. Here again, from motives of false economy, an error is likely to be made. An increase in the height of a pier necessitates a corresponding increase in the cost of the whole of the sub-structure, and in some instances in some portions of the superstructure as well. The pier at Blackpool, in Lancashire, is an example in which this mistake was originally committed. During its erection—which, owing to the unfavorable weather, made at first rather slow progress—the storms which occurred in the autumnal months indicated that the structure was being placed at too low a level. Fortunately there was time to profit by the warning, and the whole pier was raised three feet higher than had been originally contemplated. While having due regard to the height of the pier with reference to the protection of the deck from the action of storms, that dimension must not be increased beyond what is required, not only for the reason already given, but because the difficulty of access is thereby enhanced. So far as a promenade pier is concerned, this last consideration is perhaps not of much importance; but it becomes one of the points demanding the greatest care and attention when the structure is erected to accommodate the trade of a place. There is always a natural desire on the part of the proprietors of piers, wharves, and landing-places, to lessen the lift as much as possible, and it is therefore no wonder that under the circumstances the level of the surface is sometimes too low. The cause of the inundation which in March last laid under water a large portion of the districts of South Lambeth, on the Surrey banks of the Thames, was the fact that the level of the top of the walls of the various wharves was not sufficiently high. The extraordinary tide which recurred in the river at that time reached in some cases to a height of more than a foot over the walls.

The weakest portions of a long pier—that is, one which is not less than a quarter of a mile in length—are, in a constructive sense, the shore end, or commencement, the central part, and the termination or head. We may consequently divide a pier into three parts, each of which ought to be able to stand alone without the assistance of the intermediate connecting lengths. In other words, if we suppose these intermediate lengths to be carried away by a storm, these three nuclei, or *points d'appui*, ought to remain intact. On the other hand, if the latter are destroyed, the intermediate parts will go likewise, and are not expected to do otherwise. Viewing the subject in another light, the actual erection of the pier may be carried on in one of two ways. The work may advance, as is usually the case, gradually and progressively from the shore; or the shore ends, central part and head may be first constructed, and the remainder subsequently added. Whichever course may be adopted—and supposing the theoretical assumptions respecting the stability of the three points to prove true in practice—there would still remain the chance of the intermediate portions being carried away before they formed part and parcel of the whole continuous structure. The absence of this continuity between what are assumed to be the self-supporting parts of the pier, constitutes the danger and risk incurred in its erection. It is far more likely to suffer from the effects of stormy weather while in a disconnected and incomplete condition than when in a finished state. The whole structure is so braced that it cannot sway laterally, and any tendency of this kind in a longitudinal direction must be counteracted by the pier being immovably tied at the shore end, at the central part, and at the head, or at any rate at the first and third of these points. Too much care and attention cannot be bestowed upon the bracing of the head of a pier. As a rule, the heads of piers are too small, and do not afford that strength and stability which they not only require themselves, but which are also necessary to the security of the rest of the structure.

REPORTS OF ENGINEERING SOCIETIES.

INSTITUTION OF CIVIL ENGINEERS.—At the sixth ordinary meeting of the session 1874–'75, held on Tuesday evening, the 15th of December, Mr. Thos. E. Harrison, President, in the chair, the first paper read was on "The New South Breakwater at Aberdeen," by Mr. William Dyce Cay, M. Inst. C. E.

The New South Breakwater formed part of the scheme of improvements now being carried out by the Aberdeen Harbor Commissioners under the Act of 1868, and was completed in the autumn of 1873. After describing the object of the breakwater, and the design upon which it was originally commenced, the author observed that in carrying out the work, various methods of building with concrete in a liquid condition deposited *in situ* were tried. The results proving satisfactory, the original design was to some extent departed from, and the portion of the work in deep water was executed in the following manner: The foundation, after the loose material had been removed, was laid with large bags containing liquid concrete; the work was then carried up with concrete blocks, of from 10 tons to 24 tons each, to 1 foot above low water of ordinary neap tides, from which level to the roadway, a height of 18 feet, it consisted entirely of liquid concrete deposited *in situ*. The toe of the breakwater was protected by an apron of bags, each containing about 100 tons of liquid concrete. Near the shore the foundation rested on rock, then, for a space of 100 feet, on boulders and gravel, and the outer portion was clay mixed with gravel and covered with large stones. The bags containing the liquid concrete were deposited in the foundations from iron skips, the bottom of which opened on hinges by the action of a trigger, and so discharged the bags. The sea staging consisted of a solid timber framework supported on Oregon pine masts, which rested on cast-iron shoes, each weighing 11½ cwt., and having a socket on the upper side to receive the foot of a mast. The sole of each shoe was a flat octagonal plate 3 feet 8 inches across. The top of each mast had a cast-iron cap, with a socket 4 feet deep, the upper side being a flat, triangular table, measuring 6 feet 10½ inches by 6 feet 2 inches, to which the timber superstructure was fitted. The weight of each cap was 32 cwt. The superstructure of timber girders was composed of large logs keyed and bolted together, no trusses being used, and the whole was braced with ties and struts, and, for additional security, tied to anchors. It was stated that a length of 108 lineal feet of the staging had been erected in four weeks.

The system of building with liquid concrete deposited *in situ* above low-water level was then described. With respect to progress and cost, it appeared that from the time the machinery was fairly at work, about 300 lineal feet had been completed per annum; and that, taking into account the value of the plan now being used on another of the Aberdeen Harbor works, the cost had not exceeded the estimate. The total length of the breakwater was 1,050 feet, and on this £76,443 had been expended. In conclusion, the opinion was expressed that concrete blocks of the ordinary size of from 10 tons to 20 tons each were not suitable for building a solid breakwater on sand or other soft material, and it was recommended that the parts of such a work below low water should be in blocks of from 100 tons to 200 tons weight each, and that some of these blocks might with economy and advantage be deposited in a liquid state in bags.

The second paper read was on "The Extension of the South Jetty at Kustendjie, Turkey," by Mr. George Lenton Roff. This jetty, previous to its extension, was 450 feet long, and was protected against gales by a mole of pierre perdue and concrete blocks. The design for the extension was governed by the following points: It was to be regarded as a breakwater, to be so constructed as to avoid the necessity of lengthening the mole, and the existing traffic accommodation and loading-berths were to be interfered with as little as possible. These considerations made large concrete blocks necessary, and restricted the space available for operations to the last 50 yards of the existing jetty. The design adopted was that of concrete blocks, weighing about 30 tons each, resting upon pierre perdue. The stability of the blocks was tested by leaving five tiers untopped from September, 1872, to July, 1873, at the then extreme end of the work. They were exposed to very heavy seas during the winter; but none of them were disturbed, except by ordinary settlement. The total length of the pier was 253 feet 6 inches; and the total cost, including that of the plant, had been about £13,000. The blocks in every case settled vertically, without disturbing the line of direction, the only effect of settlement being to open the joints of the concrete cap; and the slight openings at these points could easily be filled up with cement. The original design was by Mr. Liddell. The work had been executed by the author for the Danube and Black Sea Railway and Kustendjie Harbor Company (limited).

IRON AND STEEL NOTES.

The "Sheffield Telegraph" states that Mr. John Heaton, C. E., at present resident in Sheffield, is coming to the front again with a system of making iron and steel which, if carried to a successful issue, promises to mark a new phase in the history of these industries. This gentleman has studied the manufacture of iron and steel from a chemical point of view, and has succeeded in producing high-class products in a shorter time, at less expense, and with greater ease, than any producer who has yet preceded him; and the results of his discoveries must have an enormous influence on the trades with which he is connected. We believe that Mr. Heaton is the owner of three several patents, and that in connection with a company he, until the year 1869, successfully carried on the manufacture of iron and steel at Langley Mill. A litigation arose which has proved a long one, but Mr. Heaton is at last in possession of his patents, which he intends to work as soon as possible.

Economy of Fuel in Furnaces.—M. Foucault, in a report to the Industrial Society of Rheims, combats the idea that the smokelessness of a fire can effect a notable saving in the amount of fuel burnt. He alleges also, on the other hand, that a considerable loss of economy is produced by smoke-consuming apparatus. He brings, in support of his opinion, the long series of observations made by the Industrial Society of Mulhouse, which have proved that, with the ordinary boiler furnaces, it is only necessary to consume from 125 to 150 cubic feet of air for each pound of coal, while furnaces, for the most part, pass twice that quantity. If the draught be reduced in quantity, much smoke is evolved, but the products of combustion, circulating more slowly, part with their heat more readily to the boiler flues. It is further proved that the best means of reducing the loss of heat by the chimney is the use of feed heaters in the flue, so as finally to reduce to 200° the products of combustion, which are often discharged as hot as 400°. Feed-water heaters well set, will produce an economy of from 11 to 20 per cent., with a reduced draught. The conclusion is that furnaces with large area and suitable feed-heaters are the most economical in all respects. But in order to obtain the best results much care is needed in stoking. A little at a time and often should the coal be spread over the front of the fire, and the bright coal pushed back to the bridge. At the same time, the least possible quantity of cold air should be admitted.

New Method of Rerolling Rails.—The Pittsburgh "Manufacturer" says: "A new method of rerolling rails has been invented by J. P. Edwards of Cleveland, and patented by Messrs. Edwards and Rogers. The old rails of 60 pounds are cut in lengths of 15 feet, and reduced to 25 and 30-pound rails by passing through a set of rolls turned for that particular purpose. The rail is finished in five passes. The advantage of this invention is obvious and has been long sought after. The North Chicago Rolling Mill of Chicago are introducing the patent into their mill. The same party also patented a pair of billet rolls to reduce steel rails to billets without lap or crease; also to roll splice bars from crop ends of rails."

Calcination of Native Oxides of Iron.—In Sweden, and most other countries where iron is smelted with charcoal, the universal practice, from the most ancient times, has been to subject the nearly pure native magnetic and specular oxides of iron to a preliminary calcination before charging them into the blast furnace. The reasons for so doing, if we except the statement that in practice it has been found better, have been variously given, and metallurgists generally are not agreed as to the true explanation as to why this preliminary calcination should be necessary. The results of an experimental inquiry into this subject have recently been published by M. H. Tholander, in the first and second numbers of Jern Kontorets Annaler for this year, which, however, have reached us too late to prepare an abstract for this present report.—*Journal of Iron and Steel Institute.*

FLUXES FOR STEEL.—In his work on the treatment of phosphoric irons, both wrought and cast, Lancauchez gives the composition of the fluxes made use of by MM. Verdie and Micolon, for the manufacture of steel by means of iron and steel scrap. The following are two recipes employed by these gentlemen:

No. 1.	Kilogrammes.		
Peroxide of manganese	0.750	to	2.000
Tungstate of iron	0.200	"	0.700
Borax	0.300	"	0.900
Carbonate of soda	1.000	"	2.000
Quick lime	0.000	"	0.500
Pulverized charcoal	0.150	"	0.600
Total for 100 kilogrammes (nearly ½ cwt.) of cast steel	2.400	to	6.700

No. 2.	Kilogrammes.		
Peroxide of manganese	0.500	to	2.300
Tungstate of iron	0.150	"	0.750
Borax	0.400	"	1.090
Carbonate of soda	1.500	"	3.000
Sal ammoniac	0.150	"	0.300
Pulverized charcoal	0.100	"	0.500
Total for 100 kilogrammes (nearly ½ cwt.) of cast steel	2.800	to	7.850

These substances were well ground together, then calcined in old worn-out crucibles placed in the furnaces at a low heat, so that, during the night, perhaps for twelve or fourteen hours, the mixture was exposed to a temperature of from 1,200° C. (2,292° Fahr.) at the beginning, to 500° C. (932° Fahr.) at the end.

It is easy to see that, in this calcination, manganate of soda and basic borate were produced, and that the sal ammoniac was completely decomposed under the form of chlorine and chloride of iron evolved by the tungstate of iron; then, the water in combination with the borax and the carbonate of soda, being partially decomposed at temperatures of 600° C. (1,112° Fahr.) was obliged to give up some of its oxygen to the peroxide in order to facilitate the formation of the manganates of soda and of lime.

It will be remarked that in this chemical process there is no trace of silicium in the products mentioned, which, with respect to the acid, had played the part of the most energetic bases, thus accounting for the fact that their use was only possible in plumbago crucibles; now, as it was by chance that MM. Verdie and Micolon were unable to procure in Paris other crucibles than those of plumbago, which came from England, it is due to this chance, says M. Lancauchez, that a process has now succeeded, which before had always failed.

The recipes of MM. Verdie and Micolon approach very nearly to that of M. E. Gallet:

	Kilogrammes.		
Alumina	0.500	to	1.000
Clay	0.120	"	0.200
Pulverized charcoal	0.500	"	0.500
Carbonate of lime	0.380	"	0.420
Carbonate of potash	0.180	"	0.300
Carbonate of soda	0.020	"	0.020
Caustic potash	0.500	"	1.000
Oxide of manganese	0.040	"	0.040
Resin	0.040	"	0.050
Muriate of soda	0.010	"	0.010
Sal ammoniac	0.500	"	1.000
Borax	0.500	"	1.000
Water	40 per cent. of the weight.		

This mixture must be made with care. The quantity to be used per 100 kilogrammes (nearly 2 cwt.) of steel, varies from 3 to 7 kilogrammes (about 6 lb. to 15 lb.)—*Iron.*

DIRECT MANUFACTURE OF STEEL.—It may have been thought by some that, with the Bessemer steel process, we had seen the last startling innovation in the commercial manufacture of steel; but, according to the latest news from Vienna, we are, perhaps, on the threshold of a further startling revolution in the metallurgical processes for the production of commercial steel. It is that of "direct" production of pure steel from the ore. For many years metallurgical engineers have been endeavoring to substitute the treatment of minerals in cupola or blast-furnaces, by their reduction in reverberatory furnaces. All efforts hitherto attempted in Europe or in the United States have failed to bear any considerable fruit. It is now thought that this problem has at last been solved.

The first run of steel took place on the 27th of September last, at the ironworks of Verrières (Vienna) belonging to M. Robert de Beauchamp, produced by direct treatment of the ores in a reverberatory gas furnace on the Ponsard system. The inventor himself conducted the operation with the assistance of M. Peripé, Director of the Société Genérale de Métallurgie at Paris. The apparatus was essentially composed of a gazogene, which transformed the "combustible" into the gaseous state; a large chamber of many compartments, in which the operations were conducted, and an apparatus in brick called the "Regenerator," which absorbed the waste heat of the furnace, and gave it back in the form of hot air. The compartments of the working chamber served successively for the reduction of the ore, for the reactions that had to be accomplished, and finally for the fusion of all the materials, so that the separation by the difference of densities should become possible.

These different phases of the operation required very different temperatures, and this is what the form of furnace is eminently suited to supply. At the charging doors furthest from the combustion chamber the furnace is only of a red heat, while nearer the combustion chamber the heat is so intense that one cannot look into the furnace without being dazzled. This temperature is estimated at 2,000° C.

The success has been greater than was hoped for. The result obtained at Verrières showed clearly the possibility of producing steel direct from the ore, without passing through all the processes hitherto used. If the actual practical results—and we can see no insuperable impracticability in the process—should at all approximate to the above startling facts, we cannot but think that our ironmasters have been outdone on their own ground, and that this is the foreshadowing of a further great revolution in the iron trade.—*Iron.*

ELECTRO-DEPOSITION OF IRON.—An interesting paper was read by M. Volger before the Frankfort Society of the Physical Sciences last autumn, which we have not seen properly noticed in England, and from which we extract the following notes relative to the treatment of iron:

Forty years ago M. Peligot succeeded in reducing chloride of iron by means of hydrogen gas, obtaining regulus of iron in octahedric crystals; and he also succeeded in preparing small malleable plates.

In 1846, M. Boettger succeeded in decomposing chloride of iron by galvanism, but he soon found that a mixture of ammoniacal sulphate and chloride of iron was more advantageous for the purpose, and he prepared this mixture very simply by dissolving together two parts by weight of sulphate of iron and one part of sal ammoniac. He employed a piece of iron plate at the positive pole, and at the other a piece of metallic iron scraped bright. He thus produced beautiful iron coins, the metal of which was extremely hard and steel-like, but so brittle that the medals often broke in pieces when taken from the moulds. It was therefore thought impossible to make any industrial use of this methed.

In 1859, however, M. Jacquin published his method of depositing an excessively thin coating of iron on engraved copper plates, and for this purpose he made use of M. Boettger's process.

Very lately the deposition of iron by galvanism has been greatly improved by M. Klein, of St. Petersburg. In 1808 he produced before the Academy of Sciences, of that capital, the results which he had obtained by means of an ammoniacal solution of sulphate of iron, and a Meidniger battery with a piece of iron plate at the positive pole. With these he produced, by precipitation of the iron, not only entire plates of steel from the hardest to the softest, for the reproduction of engraved copper plates, which united the advantages of the softness of the copper for the engravers and the steel-like hardness of the iron for printing from. He also applied the method to the production of various articles in iron. In all cases the iron precipitated by M. Klein is very brittle, and he found that it was combined with hydrogen, and that its specific gravity was not more than 7.675, that is to say, a little more than rolled iron, but the hydrogen was driven off by annealing, which gave the iron the density of 7.811, which is greater than that of hammered iron, and it then became perfectly malleable, eminently flexible and elastic, and capable of being welded; in a word, possessing all the characteristics of excellent hammered iron.

M. Volger exhibited to the Society steel reproductions of engraved plates prepared by M. Klein, a block made up of strips of the deposited iron welded together, forged, filed, and polished, and a shield reproducing perfectly an elaborate *repousse* composition of the "Battle of the Amazons," with a plateau weighing 15 lbs. The most valuable application of electro-iron was pronounced by M. Volger to be in its employment in stereotype works, and especially in the case of printing in colors for the Government bank notes, checks, stamps, etc., as iron is not affected by mercurial pigments which ruin copper, type, and other metals.

CEMENTATION OF IRON.—We find in the *Bulletin de l'Association Scientique de France* a study, by Boussingault, on the cementation of iron for steel. The difference of the material before and after cementation was determined by the most accurate methods with the following result:

	Before Cementation.	After.	Difference.
Weight used......	4949.45	4994.20	+44.45
Iron..............	4905.00	4914.30	— 0.70
Carbon...........	5.84	49.69	+43.85
Silicon............	5.20	5.34	+ 0.14
Sulphur	0.59	0.30	— 0.29
Phosphorus.......	4.95	6.24	+ 1.29
Manganese.......	10.99	10.99	none.
Other elements...	16.98	17.33	+ 0.35

The most important deduction from the above is the fact that the sulphur is eliminated by fusion to the extent of one-half; a fact probably explaining the better quality of steel made from cemented iron. The loss of iron is probably due to the formation of chloride by reaction on the alkaline chlorides, in the cement powder.

RAILWAY NOTES.

RAILWAY PROJECTS IN THE EAST.—At a recent meeting of the Société de Géographie, a letter was read from M. de Lesseps, stating that his son, M. Victor de Lesseps, and Mr. Stuart, an English engineer, had returned, after ten months' exploration on the frontiers of Afghanistan and among the Himalayas. Their observations and unpublished geographical works placed at their disposal by the Indian Government gave a choice of three routes for railway communication between India and Russian Asia:—1. From Peshawur to Caboul, Balkh, Samarkand, Tashkend, Fort Orsk, and Orenbourg. 2. From Peshawur by the valley of the river Caboul, Chitral, the Pamir table-land, the basin of the Yarkand river, the towns of Yarkand, Kashgar, Kokand, Tashkend, Ekaterinbourg or Orenbourg. 3. From Lahore to the course of the Seloum, the river Nedridge, Shyok, Karakorum, the rivers of Yarkand, Kashgar, the towns of Kokand, Tashkend, valley of the Jaxartes, and Ekaterinbourg or Orenbourg. The first and second of these, though practicable from an engineering point of view, seem excluded on other grounds; fanaticism and civil wars prevailing in the territory to be traversed up to the Russian possessions would even preclude surveys from being made, and both Russia and England would be hostile to any project involving their intervention in the affairs of Afghanistan. As for the third route, which alone seemed feasible to the explorers, the crossing the Himalaya and Cashmere chains would be a serious undertaking; but the explorers found out that by following the valley of the Seloum and ascending to Srinagur, the capital of Cashmere, great heights might be reached by gradual slopes, as was stated before their departure by the late M. Elie de Beaumont, whose statement that the rock to be cut in case of a tunnel between one valley and another would be softer than in European mountains, had also been confirmed. The greater length of the line would be compensated by security to life; for, whereas no traveller could go from Peshawur to Tashkend by Afghanistan without danger, a journey between Lahore and Yarkand offered no serious perils. The explorers met Mr. Russell in the Himalayas with 600 mules laden with English goods, while merchandise from Yarkand is now sold in London. Cashmere, moreover, is under a tributary of the Indian Government. Eastern Turkistan or Kashgar is governed by an intelligent young sovereign, Yakoob Beg, who had just concluded a liberal treaty with England. His capital, Yarkand, with 300,000 inhabitants, would become the junction between the Anglo-Indian and the Central Asian lines, as also the starting point of a direct line to China. When England, added M. Lesseps, sees

Russia extending her railways from Central Asia to Tashkend and the frontiers of Eastern Turkistan, she will not like to remain outside the great commercial traffic which will result from it. She will hasten to promise the survey and construction of a railway facilitating her commercial interests with Central Asia and Western China.

Native Railway Engineers for India.—It has long been apparent that if the extension of Indian railways was meant to keep pace with the expressed desires of the Government, the lines must be conducted by native agency with a moderate amount of European supervision. At present few of the natives know much about practical mechanics, and men who have a familiar acquaintance with the branches which are most essential in railway practice are extremely rare. The mere introduction of European skill and appliances in various manufactures and public works, especially railways, which has taken place to a large extent of late years, has indeed produced an unpremeditated education in mechanics among the quick-witted Hindoos; and natives who can manage a steam engine have long been found in the presidency towns. There are a few of them who are even capable of driving a locomotive engine, although many engineers of experience express doubts whether the nerve and readiness of mechanical resource required to make a good driver are likely to be found largely among the natives of India. The local government, which evidently does not share in this opinion, has determined to make a systematic attempt to train native engine drivers and mechanics of all kinds, as well as plate-layers, for the service of the State railways to assist the European agency in this department. If the experiment should prove successful, not only will a considerable saving be effected, but a new field of employment will be opened up for the natives themselves. In regard to plate-laying, it is thought that the object may be obtained by allowing to the inspectors on the various State railways an apprentice fee for every native they instruct and turn out a really qualified foreman plate-layer, capable of superintending the maintenance of twenty to thirty miles of railway. Such men could readily command ten shillings a week, which is excellent local pay; and Lord Northbrook is anxious that the experiment should be tried immediately. As respects the instruction of natives as engine drivers, it is of course essential that a driver should have served in workshops, and be qualified not merely to keep his engine in good going order and drive it, but if anything goes wrong, to find out the source of the mischief and rectify it. Hitherto few natives have passed from the workshops to be employed as drivers; but the Government of India thinks that this state of affairs might be remedied without much difficulty. In the opinion of those who constitute it, with a proper selection of intelligent men, physically fitted for such work, and with careful training, both in and out of the shops, a better result may be looked for, more especially with the lighter engines and slower speed of the metre gauge lines. A great deal will naturally depend on the earnestness and aptitude of the instructors, and especial care must be taken to insure a close control over the men, particularly as regards the proper charge being taken of the engines consigned to their hands. It has also been suggested that an attempt should be made to train some of the native sappers and miners to the duties connected with the construction and maintenance of railways. Suitable occupation could readily be found for them in times of peace, while in war time they would naturally prove very useful. This is a question which remains open for the consideration of the military authorities; but if it should meet with their approval, it would be easy to arrange on the State railways for the training of a company, or a selected portion of each company, on all the special details of railway construction, etc.; and it is probable that from among such a number of men individuals would be found willing to go through a course of training in workshops, and to perform the duties of engine drivers efficiently when the educational period ended.—*The Engineer.*

ENGINEERING STRUCTURES.

Port Said.—The Suez Canal Company is lengthening the western mole of Port Said, and clearing away the deposit which on that side of the entrance was fast encroaching upon the already somewhat narrow channel leading into the port. It is intended to carry the breakwater on that side out into six fathoms of water, when its total length will be about 10,340 feet. Some 200 feet were completed last year, but the whole will not be finished for another three years at least. The company has taken over the concrete manufacturing establishment of Messrs. Dussand, and it is now making concrete on its own account. Hydraulic lime, sea sand, and water were formerly used, but small stones obtained from the Greek Islands have now been found to answer the purpose better than sea sand. The breakwaters as barriers to the sea are everything which could be desired, but below water there are numerous open spaces through which sand brought down by the Nile current finds its way.

New Harbor at Dover.—Her Majesty's government will, it is authoritatively stated, early in the next season of Parliament, introduce a bill for the speedy execution of a plan which has been recently agreed upon between the various public departments for the construction of a large military and general harbor at Dover. The harbor which the government have resolved to construct will cover an area of about four hundred acres, with a depth varying at low water of spring tides from one to six fathoms. It will serve at once as a packet harbor, a coaling-station for men-of-war of all sizes, a commercial harbor to be used subject to the payment of tolls, a depot for munitions of war, and a harbor of refuge on a small scale. Such a harbor, protected by the batteries near the castle and on the western heights, and by a large fort now in course of construction on the Admiralty Pier, would be of great advantage to England in case of a European war. The whole coast of France from the mouth of the Seine, and the whole coasts of Belgium and Holland, would be commanded by a small fleet which should make Dover the basis of its operations, and, indeed, almost any North Sea fleet would naturally send its vessels to coal at Dover, if accommodations for the purpose were once provided within so short a distance of London, and opposite the new harbor which has just been undertaken by the French government between Calais and Boulogne. It is expected that the bill will pass without opposition by the end of March, and that the works will be actually commenced by June next at the furthest. These works will cost, as near as possible, a million pounds sterling. This money it is proposed to obtain from the Public Works Loan Commissioners, at a rate of 3¼ per cent., in such sums as may be from time to time required, so that Parliament, having once passed the bill that is now being prepared, will not be called on to provide any more funds. The cost of the works will be refunded by a toll of 1 shilling per head on passengers landing or embarking, by an annual rental from the South-Eastern and the Chatham and Dover Railway Companies, and by the usual harbor dues, ground rents, receipts for wharfage, and the like, the total annual revenue being calculated at something between £35,000 and £40,000. This will pay the interest and provide a sinking-fund, by means of which the cost of the works will be repaid in something like, it is believed, twenty-five or thirty years, or, if the traffic continues to increase in anything like its present ratio, in a much shorter period. The works will be carried out under the direction of Mr. Edward Druce, C. E., who has been for twenty years resident engineer at the Admiralty Pier. The materials will be almost exclusively the concrete blocks which have been so largely used below water in the existing works, and some of which that have been immersed for fifteen years, and have recently been recovered, show no signs of deterioration, and are, indeed, additionally bound together by growths of molluscs. When the new harbor is completed—even when the new packet pier is finished—and when the French government has got the new port at Audrecelles, that has just been sanctioned, ready for use, there will be no longer any excuse, whether the *Castalia* and *Bessemer* succeed or fail, for the inferiority of the steamers on the Straits of Dover to those beautiful boats which have now been running most successfully and remuneratively for over ten years between Dublin and Holyhead; indeed, there will be no reason why the passage from Dover to the new port under Cape Grisnez should exceed an hour, or seventy minutes at the most, in ordinary weather, while the mails and passengers will be able to cross, no matter how bad the weather might be, which is not always the case at present.—*Iron.*

BOOK NOTICES.

THE BLOWPIPE; A GUIDE TO ITS USE IN THE DETERMINATION OF SALTS AND MINERALS.—Compiled from various sources by GEORGE W. PLYMPTON, C.E., M.A. New York: Van Nostrand, Murray and Warren Streets. London: Trübner & Co., Ludgate Hill. Price $1.50.

For the rapid determination of the approximate composition of minerals the blowpipe is, when ordinary care is used, thoroughly reliable, and at the same time most convenient for the practical man, owing to the extreme portability and compactness of the whole apparatus required for making the tests; and to facilitate the acquisition of the knowledge necessary for its successful use, Prof. Plympton, of the Polytechnic Institute, of Brooklyn, N. Y., has compiled this very useful little volume, designed especially for the learned. In the first and second parts, which treat of the apparatus and reagents, and of the general examination, Sheerer and Blanford have been chiefly followed, while in the third part, in which the various methods for the determination of minerals, by the aid of the blowpipe, are explained, Guerout's Guide Practique, translated from the manual of Dr. Fuchs, of Heidelberg, has been taken as the basis, but throughout the volume Prof. Plympton has introduced emendations and improvements of considerable importance, and which adapt the book to the requirements of English and American readers. It is remarked, that, perhaps, during the last fifty years no department of chemistry has been so enriched as that relating to analysis by means of the blowpipe. Through the unwearied exertions of men of science the use of this instrument has arrived at such a degree of perfection that we have a right to term its use analysis "in the dry way," in contradiction to the analysis "in the wet way." The manipulations are so simple and expeditious, and the results so clear and characteristic, that the blowpipe analysis not only verifies and completes the results of analysis in the wet way, but it gives in many cases direct evidence of the presence or absence of many substances which would not be otherwise detected without a troublesome and tedious process, involving both prolixity and time; for instance, the detection of manganese in minerals.

It being essential to the blowpipist that he should be not only well acquainted with the nature and use of the various pieces of apparatus, but that he should know which form is the most convenient and of greatest general utility, Prof. Plympton devotes a couple of dozen pages to the consideration of the utensils—the blowpipe, the lamp, the charcoal, and platinum supports, iron spoons, glass tubes, and other apparatus necessary; and then describes the reagents, and explains the method of testing their purity. It is gratifying to find that the author has not only adopted the modern chemical notation, but that he has also, in one or two cases, used the metric measures. It is a most remarkable circumstance that the Americans, usually so quick to recognize improvements, and so clever in making them themselves, should in the two important points of chemical notation, and the adoption of the metric system of weight and measures, have suffered themselves to be left so far behind by less progressive European nations. Even in England, the very hot-bed of prejudice, the metric system, from its unquestionable superiority, has long since been adopted by the leading scientific and especially chemical writers, although the stupidity of the general public has not yet been overcome, and in Germany, where the relations with France have rendered anything of French origin particularly unpopular, the undoubted advantages of the metric system have led to the adoption of the exact half kilogramme as the Zollpfund, or unit of weight, the Zollcentner being 50 kilogrammes, and the Ton 1,000 kilogrammes. Yet in America, where the existence of a decimal coinage renders the adoption of a corresponding system—the metric system—specially desirable, there is as much opposition as if the nation were antiquated and effete. Let us hope the time is not far distant when the metric system will become universal. Having been taught the use of the apparatus and reagent to be employed, the student is next introduced to the initiatory analysis—the examinations with the glass tube, open tube, and charcoal in the platinum forceps, borax bead, microcosmic salt, and carbonate of soda; and the confirmatory examinations, ample tables being provided to facilitate his researches. In the third part, treating of the determination of minerals by the aid of the blowpipe, the various minerals are classed according to its behavior on charcoal, whether it volatilizes or burns, emits a given odor, gives off fumes of antimony, coats the charcoal, or leaves a characteristic residue; to its behavior with carbonate of soda, in the borax lead, or with cobalt solution; according to the effect produced upon it by hydrochloric acid, and so on, so that the group to which a mineral under examination belongs is readily ascertained, and there will be scarcely more difficulty in deciding which particular member of the group it is.

For the practical man requiring a comprehensive and portable volume few better than Prof. Plympton's could be recommended. The general character of Scherer and Blanford's is too well known and appreciated by professors and students to render any special commendation of the first and second parts necessary; while with regard to the third part, the arrangement is at once simple and excellent, it is concise, yet gives all the necessary information, leaving really nothing to be desired by those who take the book for their guide.
—*London Mining Journal.*

A Handbook of Applied Mechanics. By Henry Evers, LL.D. London and Glasgow: W. Collins, Sons & Co., 1874. Price 75c.

This is one of Collins's Elementary Science Series, and is quite equal in merit to the other members of perhaps the most valuable of all the cheap collections of scientific manuals which recent events have educed in such overwhelming numbers. After a general introduction, in which the elements of applied mechanics are recapitulated, the author treats in succession of the properties of the chief woods used by machinists, and then passes to the metals, explaining the modes by which they are procured and their various properties. Water as applied for mechanical purposes is next treated of, and then follows a practical dissertation on the strength of materials, and a description of the tools and machines employed in the mechanical arts. Well-executed illustrations are freely supplied, with a useful and sufficiently copius index, a prime requirement in a book of this, or indeed any kind.—*Iron.*

Hints to Young Engineers. By J. W. Wilson, C. E. London. For sale by D. Van Nostrand.

A useful *brochure* by Mr. J. W. Wilson, C. E., Principal of the Crystal Palace School of Practical Engineering, has been published by Messrs Spon, of Charing Cross. The value of the practical advice, of which the little work contains much, is not impaired by the pleasant vein of dry humor that crops up at intervals. It is very readable, and thoroughly practical, such, in a word, as few readers, professional or other, can fail to enjoy and profit by.

Mineralogy. By F. Rutley, F. G. S. London: Thomas Murby, 1874.

Into this little manual, which is one of Murby's Science and Art Department Series, the author has compressed a large amount of instructive matter, very lucidly arranged, and selected with judgment, so as to suit the requirements of beginners, the minerals being grouped according to their most prominent basic constituents, and each group being prefaced by a sufficient description of its leading characters, chemical and physical. The introductory definitions and general descriptions will be found very useful, as will also the instructions in the use of the blow-pipe; and the diagrams in the crystallo-graphic portion are drawn on a novel plan, and are better calculated to give exact ideas of the form and relation of the planes of the crystals than that on which they are generally represented. The subject of polarization is treated with unusual clearness.—*Iron.*

Color. By A. H. Church, M. A. London: Cassell, Petter & Galpin. Price $1.00.

This is a new edition to Cassell's Technical Manuals. It is abundantly and beautifully illustrated, and will be read with interest by the general reader, but it is furthermore so complete in its array of facts as to be of valuable service to the student and lecturer.

Manual of Toxicology. By John J. Reese, M.D. Phila. J. B. Lippincott & Co. $5.00.

Although this field of scientific labor has been ably worked already, and the results abundantly recorded, yet we trust the present treatise will be well received.

The reputation of the author will secure earnest attention to his writings. Much is written that has been presented before, but in a familiar, easy reading style that is the author's own. More than the usual space is devoted to the medico-legal part of the subject; and two subjects—"Post-Mortem Imbibition of Poisons," and "Duties and Privileges of Medical Experts" are treated for the first time at considerable length.

Manual of Determinative Mineralogy, with an Introduction to Blow-Pipe Analysis. By Prof. George J. Brush. New York: John Wiley & Son. For sale by D. Van Nostrand. $3.00.

This excellent supplement to the "Descriptive Mineralogy" of Dana has been long expected, and will prove very acceptable to students.

The first portion of the work is devoted to a "Systematic Course of Qualitative Blow-Pipe Analysis," mostly arranged from Berzelius and Plattner, and is quite complete enough as a preparation for the remaining portion of the work—Determinative Mineralogy. This portion consists entirely of tabular classifications of minerals, based upon the reactions afforded by "simple chemical experiments in the wet and dry way."

It is an indispensable aid to the student of mineralogy.

Outlines of Proximate Organic Analysis, for the Identification, Separation, and Quantitative Determination of the More Commonly Occurring Organic Compounds. By Albert B. Prescott, Professor of Organic and Applied Chemistry in the University of Michigan. New York: D. Van Nostrand, 1875. 12mo, pp. 192. $1.75.

This is the first and only book published in the English language which attempts to give, in concise form, the reactions of organic substances. Proximate organic analysis has not yet been reduced, like mineral analysis, to one complete system. For many organic substances there are no distinct tests, and no means have been discovered for separating them from other bodies with which they are combined. There are, however, certain classes of bodies which permit of isolation by fractional distillation, by solution, or by precipitation, and some of these, like the alkaloids, give characteristic colors with certain oxidizing agents. Many other well-known organic principles give characteristic reactions when by themselves. Some of these are carefully given in works on toxicology, or in the pharmacopœias, while others are scattered far and wide through chemical dictionaries, and in the proceedings of chemical societies, and in the pages of chemical journals. Professor Prescott has done a great service to the analyst in collecting together so many of these reactions, embracing the tests for more than 200 organic principles, and publishing them in a neat little volume at a price within the reach of all.

The author arranges the organic bodies of which he speaks under the following general heads:—Solid Acids, volatile and non-volatile; Liquid Acids, volatile and non-volatile; Fatty Acids; Neutral Substances, liquid or fusible; Bases, liquid and solid; Glucosides and other solid neutral substances; Nitrogenous Neutral Bodies; Carbohydrates; Alcohols and their products. The new notation is used throughout, and the work is evidently up with the times. A book so long needed cannot fail to meet with the reception it deserves.

—*Journal of Applied Chemistry.*

MISCELLANEOUS.

The Coloration of Metals.—It is possible to color metals rapidly and at very little expense by means of covering their surface with a film of a sulphurous solution. In some minutes, by means of this composition, any objects in brass or gun-metal can be given a tint of gold, of copper, of carmine, of maroon, of bright analine blue, a paler blue, and finally a pinky white, according to the thickness of the film, which again depends upon the time during which the metal is plunged into solution. The colors thus obtained have a beautiful lustre, and if the objects have first been subjected to the action of acids or of alkalies, the colors adhere so intimately to the surface of the articles that they will resist the action of the tools used to polish them. To prepare the solution, 42.5 grammes of hyposulphite of soda is mixed with 450 grammes of water; to this must be added 45.5 grammes of acetate of lead, dissolved in 225 grammes of water. In raising this solution to a temperature of 190 deg. to 200 deg. Fahr., it is decomposed, and the sulphide of lead is precipitated in the form of black flakes. If the metal is present, a portion of the sulphide of lead is deposited on it, and the colors, as we have before described, are produced according to the thickness of the deposit. In order that they should be uniform it is necessary to heat the objects equally throughout. Iron thus treated takes a steel blue; zinc takes a brown color. If in the place of acetate of lead an equal quantity of sulphuric acid is added to the hyposulphite of soda, and the operation is carried on in the same manner, but at a slightly higher temperature, gun-metal or bronze becomes a beautiful red, then green, and finally an irradiated tint of green and red most striking and beautiful. This last color deserves remark from the fact that it is durable, which is not the case with all the other colors. It is possible to obtain most beautiful imitations of marble by means of a plumbic solution thickened by adragant (tragacanth) gum applied to bronze previously heated to 210 Fahr. It is treated finally with the ordinary solution of sulphide of lead. This solution will serve for many operations.—*Iron.*

Round the World.—An English paper says: The following comparative statement of distances, time, and fares applies to existing conditions of first-class passengers from Liverpool by the American route, and from Southampton by the Suez route.

DISTANCE, TIME, AND FARES.

Via Suez Route.				Via American Route.		
Miles.	Days.	£.	To	Miles.	Days.	£.
11,268	56	103	Yokohama	11,382	34	72
10,518	53	103	Shanghai	13,032	42	82
9,648	48	93	Hong Kong	13,002	40	82
13.259	62	102	Auckland	12,290	44	82
11.999	57	88	Sydney	13,220	47	82
11,439	56	88	Melbourne	13,780	48	82

The best statement of the aggregate fares, time, and distances that we have seen is as follows:

THE MODERN ROUTE AROUND THE WORLD.

	Miles.	*Days.*	*Hrs.*
London to Liverpool	200	—	5
Liverpool to New York [Mail Steamer]	3,000	10	—
New York to Chicago [Railway]	890	1	5
Chicago to Omaha [Railway]	490	1	—
Omaha to San Francisco [By Union and Central Pacific Railways]	1,914	4	6
San Francisco to Yokohoma	4,764	19	—
Yokohma to Shanghai [Steamer]	1,200	4	—
Shanghai to Hong Kong [Steamer]	870	4	—
Hong Kong to Calcutta [Steamer, via Galle]	3,500	22	—
Calcutta to Bombay [Railway]	1,400	2	—
Bombay to Suez [Steamer]	3,600	14	—
Suez to Alexandria [Railway]	225	—	12
Alexandria to Brindisi or Venice [Str.]	850	3	—
Brindisi or Venice to London [Railway]	1,200	3	—
	24,103	88	4

Fare for the above route......£195

Under these conditions, it is not an over-sanguine belief that the current of travel is turning more decidedly toward the American route.

Association of Foremen Mechanics.—This peculiar weakness of our practical foremen may seem a small matter to so gravely discuss, but we hold that we have in a great measure to thank this foible, or "rule of thumb," for our present superiority over many French manufacturers, and our considerable inferiority to America in the marketable production of novelties. In the case of French engineers especially, they are so fond of designing and working theoretically that the natural instinct of the eye is allowed no play, and they frequently find themselves on the wrong side for strength. Whereas, in our own workshops, we believe that the eye has often saved our reputation at the expense of imperfect theory. On the other hand, in the case of America, they are entirely without traditional precedents, and thus, when a certain object has to be obtained, the American sets to work, perfectly untrammelled in his ideas, to effect his purpose in the readiest manner. This gives a certain peculiarity and eccentricity to his designs for the commonest articles, which would strike an English eye at once, and perhaps are not to be imitated with advantage; but at the same time we see the most surprising and revolutionizing novelties, designed, manufactured, and in large demand, before we in Britain would have decided that the arrangement was practical. However, our foremen will no doubt learn wisdom, and the knowledge that "novelty" does not always mean "impracticability" by the continued success of so many transatlantic novelties, and the above Association is just the sort of place in which to do so. We wish it every success and increase; and if this should meet the eye of any enterprising unattached foreman, he cannot do better than attach himself at once to the Association; and we hope that he and all his fellow foremen will take the hint that prejudice and dogmatism are generally the mark of an *ignorant*, and not essentially of a *practical* man.—*Iron.*

Chinamen Protesting against the Introduction of Railways into the Celestial Empire.—Two very curious articles have been published by a Shanghai native newspaper, the *Hwei-Pao*, protesting against the construction of railways in the Chinese empire. The *Hwei-Pao* is of opinion that the existence of railways in Europe is too recent to admit of a judgment being formed as to their practical utility, and, moreover, that there is not sufficient business in China to render them profitable. The Chinese journal goes on to say that "tea and silk are the principal objects of commerce, and these have hitherto been forwarded to the treaty ports by river steamboats. A substitution of railways for steamboats would not effect any saving in point of time, and could not, therefore, even from the point of view taken by the foreigners themselves, be of any service to China. Admitting that a little time was gained, the Chinese would not be benefited, for the goods would not be exported more rapidly. Thus the railways would only lead to an accumulation in the ports of vast quantities of goods, which, as they could not be shipped off all at once, would fall considerably in price." The *Hwei-Pao* also says: "The accidents on the railway lines are very numerous, caused by collisions, by the engines or tenders taking fire, by the trains running off the lines, or by the bridges giving way and the trains being precipitated into the rivers below. In other cases the carriages are injured by the great speed at which they are hurried along, and the accidents are so numerous that it is often impossible to ascertain the exact number of dead and wounded. All the foreign journals are full of details concerning these accidents. But, admitting that most of these casualties are preventable, and that the trains follow their regular course, they travel quicker than the thoroughbred horse, and the people walking on the lines would have no time to get out of their way. From this cause alone the number of fatal accidents would be enormous. In all countries where railways exist they are considered a very dangerous mode of locomotion, and beyond those who have very urgent business to transact, no one thinks of using them." This latter statement cannot as yet be accepted in its entirety; but unfortunately, we have every reason to know that, so far as England is concerned, travelling by railway is "a very dangerous mode of locomotion."

—*Railway News.*

Carbonic Acid Gas as a Motive Power.—Our readers are well aware that from time to time various substitutes for steam as the motive agent of engines, more or less similar to those which are in ordinary use, have been proposed. It cannot be said that as yet any have been attended with that practical success which was to be desired. This is, however, no reason why further efforts should not meet with a more favorable result, and we have had laid before us, certain proposals which appear of a very valuable character; though of course in this, as in other matters, experience will have to decide the problem.

Carbonic acid gas naturally suggests itself as a likely subject for experiment. It may be reduced into a liquid state by the compression of its own molecules under a pressure of some 33 atmospheres, and the merest tyro will at once see what an immense reservoir of force carbonic acid gas so treated must be. Dr. D. W. Gwynne, noting this, has for some time been engaged in devising means for utilizing this property of CO_2; and has arranged a complete system for its production and application, the plans for which were forwarded by him to the Earl of Caithness some six months since.

Dr. Gwynne generates his CO_2 by the treatment of some substance containing it in combination by an acid. Limestone, chalk, the carbonates of the alkalis, etc., would yield an inexhaustible supply, and the acid might either be sulphuric or hydrochloric. Where economy of space is a consideration a bicarbonate of an alkali could be employed. But under ordinary conditions chalk or limestone would answer every purpose. The chalk, or whatever else was employed, would be acted upon by the acid in a closed receptacle or generator, a general idea of which would be supplied by one of the cylinders used in the manufacture of ærated waters. The generator would be fitted with a gauge, and suitable means for attaching it to a receiver. A double cock or collar would serve to cut off the connection with the receiver, and the gauge would show the pressure. The receiver represents precisely the steam-chest of an ordinary steam-engine, and as such an engine may, and often does, have several boilers, so to each receiver may be attached any number of generators required, determined by the needed amount of power. From the character of the fittings one or more generators may be removed or replaced without interfering with the tension of the gas in the receiver. Under the receiver Dr. Gwynne places a small furnace; and as the tensive power of the gas is greatly increased by the addition of heat—1.480 volume for each degree—the value of this arrangement will be seen.

By Dr. Gwynne's process it is easy to obtain gas which would exercise a power of 30 atmospheres without liquefaction. Such a pressure, however, would, in his view, never be required, and any graduated pressure from 1 up to 30 could readily be obtained by due regulation of the apparatus and materials. As the deadly nature of the gas (which causes closure of the glottis or attempted inhalation) requires a provision for its neutralization in its escape from the engine, Dr. Gwynne has met this by passing the escape pipe into a tank of lime-water.

Such in brief is an outline of a plan which well deserves attention. Sooner or later some substitute for steam must be found, and he is a public benefactor who labors to that end.

—*Mining Journal.*

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SKEW ARCHES.

LOGARITHMIC METHOD.

II.

By E. W. HYDE, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

In this method the soffit is cylindrical, as in the last, and the case considered will be that in which the right section is circular.

The heading joints are *planes* parallel to the P F, which, therefore, cut the soffit in ellipses, which are the h j c's. The c j c's are drawn on the soffit in such a manner as to cut each h j c at *right angles.*

Now, the angle between any two lines of the soffit remains unchanged after the development ; hence, the developed c j c's must cut the developed h j c's at right angles. Also, if two lines be perpendicular to each other, their projections on a plane parallel to one of them will be perpendicular ; hence, if the arch be projected upon a plane parallel to the P F, the vertical projections of the c j c's will cut the ellipses which are the vertical projections of the h j c's at right angles. These principles will be used in obtaining the equations of the curves.

Let A B B_2 A_2 » B′ V′ A_2 be the projections of the Ex. S., and C D D_2 C_2 » D′ V C_1 those of the soffit. O Q is the axis of the cylinder, D C_1 C_3 D_2 is the development of the soffit to be constructed from the projections, or by means of ordinates found from equations (1) or (2).

The developed h j c's are all parallel to D E O_2 F C_1, and hence may be drawn from a pattern constructed by means of this curve. Divide D D_2 into such a number of equal parts as will make the voussoirs of convenient size, and draw the h j c's through the points of division by the pattern. The length of one of these curves is equal to that of a semi-ellipse cut from the soffit by a P F, and is calculated by the aid of the following formula, obtained by integrating the differential of the elliptical arc.

If S = length of semi-ellipse, a = semi-major axis and e = eccentricity, then

$$(36)\quad S = \pi a\left(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{768} - \text{etc.}\right)$$

The *middle* h j c, $n\ o$, must be next divided up into a convenient odd number of equal parts. The division is done on the middle line, in order that the two faces of the arch may be alike. We will next find the equation of the curve $k\,O_2\,m$ of which the c j c's on the development of soffit are portions.

We have already found the equation of D E F C_1, equation (1), in considering the helicoidal method. With the origin at O_1, it is

$$y = -\frac{h}{2}\cos\frac{x}{r}$$

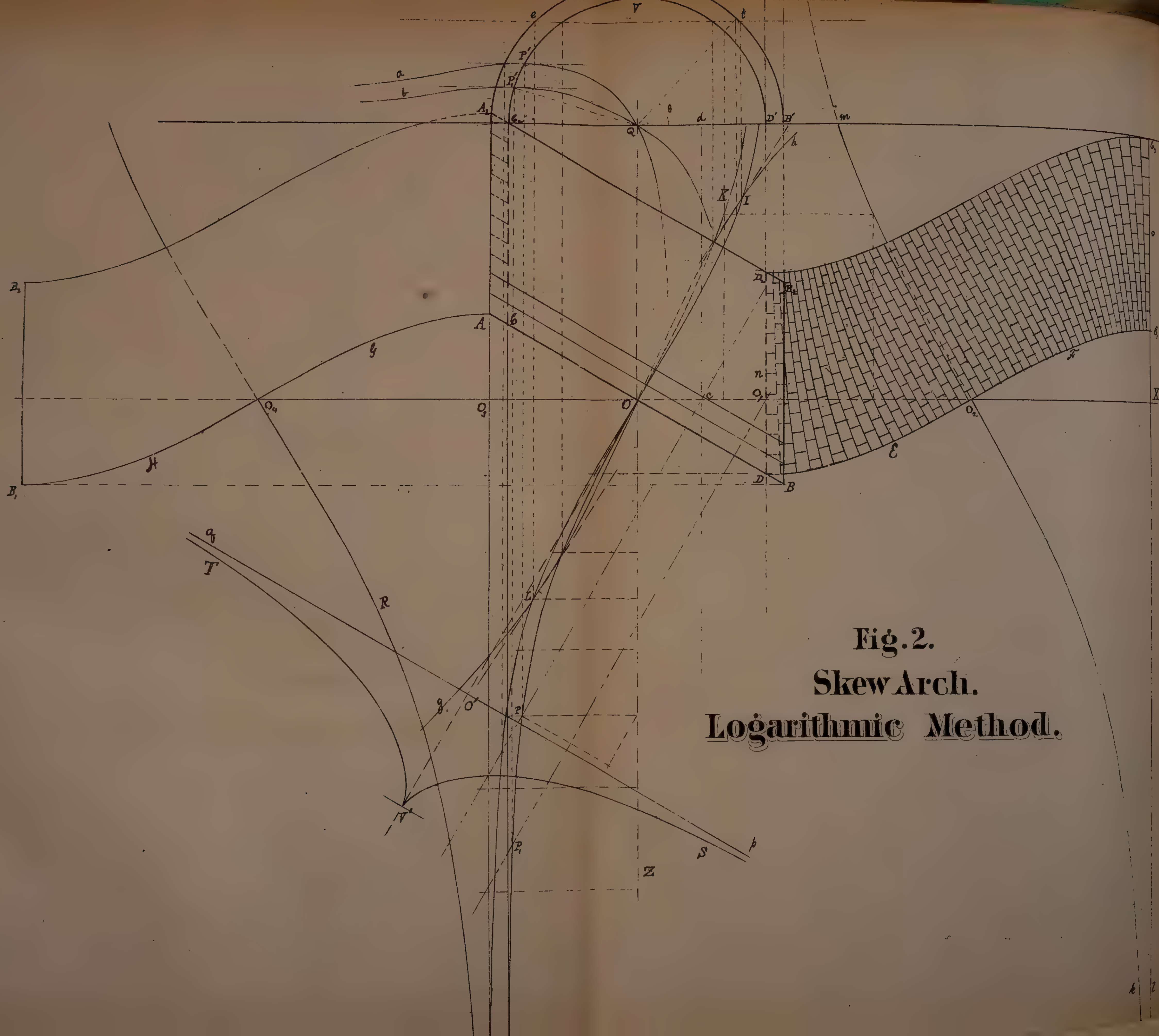


Fig. 2.
Skew Arch.
Logarithmic Method.

Differentiating

$$(37) \qquad \frac{dy}{dx} = \frac{h}{2r} sin \frac{x}{r}$$

If $k\ O_2\ m$ cut D E O_2 F C_1 at right angles, we must have, at the point of intersection,

$$1 + \frac{dy}{dx} \cdot \frac{dy'}{dx'} = o, \text{ or } \frac{dy'}{dx'} = - \frac{dx}{dy}$$

in which $\frac{dy'}{dx'}$ is the differential co-efficient of the curve to be found. Substitute the value of $\frac{dx}{dy}$ from equation (37).

$\therefore \frac{dy'}{dx'} = - \frac{2r}{h\ sin\ \frac{x}{r}}$, or dropping the primes, since the x and y in both numbers of the equation refer to the same point,

$$dy = - \frac{2r}{h} \cdot \frac{dx}{sin \frac{x}{r}}.$$

$\therefore$ Integrating

$$(38) \qquad y = - \frac{2r^2}{h} l_e\ tan \frac{x}{2r} + c,$$

in which l_e signifies Naperian logarithm.

If we let $y = o$, when $x = \frac{\pi r}{2}$, this being the condition that the curve shall pass through O_2, we have

$$o = - \frac{2r^2}{h} l_e (1) + c;$$

$\therefore c = o$, and

$$(39) \quad y = - \frac{2r^2}{h} l_e\ tan \frac{x}{2r}.$$

If we move the origin to O_2 by placing $x = x' + \frac{\pi r}{2}$, equation (39) becomes

$$y' = - \frac{2r^2}{h} l_e\ tan \left(\frac{x' + \frac{\pi r}{2}}{2r} \right) = - \frac{2r^2}{h} l_e\ tan \left(\frac{x'}{2r} + \frac{\pi}{4} \right);$$

or dropping primes and reducing

$$(40) \ y = - \frac{2r^2}{h} l_e \left(\frac{1 + tan \frac{x}{2r}}{1 - tan \frac{x}{2r}} \right)$$

In (40) if

$$x \quad o, y = - \frac{2r^2}{h} l_e (1) = o;$$

$$x = \frac{\pi r}{2}, y = - \frac{2r^2}{h} l_e (\infty) = - \infty;$$

$$x = - \frac{\pi r}{2}, y = - \frac{2r^2}{h} l_e (o) = + \infty.$$

$\therefore$ the curve is asymptotic to the right lines

$x = \pm \frac{\pi r}{2}$; *i. e.*, to l X and D D'.

If the obliquity of the arch in fig. (2) were in the *opposite direction*, the right hand members of equations (1), (38), (39), and (40) would all be *positive.*

To adapt equation (39) to convenient computation, let $x = n\ \pi\ r$, which is equivalent to dividing the distance $\pi r =$ O_1 X into n equal parts, for which ordinates are to be calculated.

$\therefore$ Substituting common logarithms for Naperian,

$$(41) \ y = - \frac{2r^2}{h} \cdot \frac{1}{M} l_a\ tan \frac{n \pi}{2},$$

in which l_a signifies common logarithm, and M is the modulus of the common system. From this equation any number of ordinates may be easily calculated for the construction of the curve $k\ O_2\ m$.

The equation of the curve K O P P_1 will next be found. This is the horizontal projection of the curve on the soffit of which $k\ O_2\ m$ is the development. Its vertical projection is of course the semicircle D' V C_2. It is plain that for any value of y the x for the new equation will bear a certain relation to the x of equation (39), and hence may be derived from it. Call the co-ordinates of K O P x' and y', x and y being those of equation (39),

$\therefore x' = - r\left(1 - cos \frac{x}{r}\right)$; whence $x = r\ cos^{-1}\left(\frac{x' + r}{r}\right)$, and $y' = y$, the origin being at O_1.

Substituting in equation (39) and omitting primes,

$$(42)\quad y=-\frac{2r^2}{h}\,l_e\,tan\,\tfrac{1}{2}\left[cos^{-1}\left(\frac{x+r}{r}\right)\right]$$

In (42) change the origin to O, and we have

$$(43)\quad y=-\frac{2r^2}{h}\,l_e\,tan\,\tfrac{1}{2}\left(cos^{-1}\frac{x}{r}\right).$$

Now we have by trigonometry

$$cos^{-1}\frac{x}{r}=tan^{-1}\frac{\sqrt{1-\frac{x^2}{r^2}}}{\frac{x}{r}}=tan^{-1}\frac{\sqrt{r^2-x^2}}{x}$$

also $tan\,\tfrac{1}{2}$

$$\left(\left(tan^{-1}\frac{\sqrt{r^2-x^2}}{x}\right)\right)=\frac{-1+\sqrt{1+\frac{r^2-x^2}{x^2}}}{\frac{\sqrt{r^2-x^2}}{x}}=$$

$$\frac{r-x}{\sqrt{r^2-x^2}}=\sqrt{\frac{r-x}{r+x}}$$

Substituting in (43) we have

$$(44)\quad y=\frac{-2r^2}{h}l_e\sqrt{\frac{r-x}{r+x}}=\frac{r^2}{h}l_e\left(\frac{r+x}{r-x}\right),$$

which is the equation of K O P with the origin at O, O Q being the axis of y.

In (44) if $x=o,\ y=\frac{r^2}{h}\ l_e\ (1)\ =o$

" $x=r,\ y=\frac{r^2}{h}\ l_e\,(\infty)=\infty$

" $x=-r,\ y=\frac{r^2}{h}\ l_e(o)=-\infty.$

Equation (39) solved for x is:

$$(45)\quad x=2\,r\,tan^{-1}\,e-\frac{hy}{2\,r^2}$$

in which e is the base of the Naperian system of logarithms. It is sometimes desirable to consider y as the independent variable, in which case the equation takes this form.

We will now give a table of values of $\frac{1}{M}l_a\,tan\,\frac{n\,\pi}{2}$ corresponding to a series of values of n, also the values of x in equation (44) for which the ordinates are equal to the corresponding ordinates of the curve k O_2 m.

TABLE III.

Values of n in Equation (41.)	Values of $\frac{1}{M}l_a\,tan\,\frac{n\,\pi}{2}$.	Values of x in Equation (44) for which y is equal to the y of Equation (44).	REMARKS.
0.01	— 4.2331	0.99951r	*N.B.*—The values of x in column 3 are to be laid off from the *axis* of the *cylinder* as the axis of y.
0.02	— 3.4601	0.99803r	
0.03	— 3.0541	0.99556r	
0,04	— 2.7659	0.99211r	
0.05	— 2.5421	0.98769r	
0.10	— 1.8427	0.95106r	*In equation* (41) *the axis of y is* O_1D_2.
0.15	— 1.4266	0.89101r	
0.20	— 1.1240	0.80902r	To obtain the corresponding values of x for the curve I O L M, *substitute* r_1 *for* r in the 3d column, the axis of y being the same.
0.25	— 0.8810	0.70711r	
0.30	— 0.6742	0.58779r	
0.35	— 0.4897	0.45399r	
0.40	— 0.3195	0.30902r	
0.45	— 0.1577	0.15643r	
0.50	— 0.0000	0.00000r	

By means of this table the curves k O_2 m and K O P may be easily and accurately constructed, as well as the curves I O L M and N R O_4 for the Ex s.

For the curve I O L M, which is the intersection of a c j s, with a cylinder concentric with the soffit, we have if x be the abscissa of K O P, x' the abscissa of I O L M and r_1 the radius of the concentric cylinder,

$$\frac{x}{x'}=\frac{r}{r_1},\ \text{or}\ x=\frac{rx'}{r_1}.$$

This value in equation (44) gives

$$(46)\quad y=\frac{r^2}{h}\ l_e\left(\frac{r_1+x}{r_1-x}\right)\text{(primes omitted).}$$

For the curve N R O_4 which is the development of I O L M, calling the abscissa of k O_2 m x, and that of N R O_4 x', we have

$$\frac{x}{x'}=\frac{r}{r_1};\ \therefore\ x=\frac{rx'}{r_1},$$

which, in equation (40), gives, omitting primes,

$$(47)\quad y=-\frac{2\,r^2}{h}\,l_e\left(\frac{1+tan\,\frac{x}{2\,r_1}}{1-tan\,\frac{x}{2\,r_1}}\right)$$

which is the equation of N R O_4 with the origin at O_4. The ordinates for this curve are the same as those for the curve $k\ O_2\ m$ when we give the proper values to x, that is, make $x = n \pi r_1$, and measure it from the line $B_1\ B_2$ as the axis of ordinates.

The curve S V′ T is a projection of the curve K O P P_1 on a plane parallel to the P F, of which $p\ q$ is the horizontal trace. In constructing an arch by this method it would be desirable to project it on such a plane, and hence this curve would be needed. It cuts at right angles the projection on its plane of any ellipse cut from the soffit by a plane parallel to the P F, and its equation is found by a process similar to that by which equation (39) was obtained. Let $q\ p$ be the axis of x and O′ V′ the axis of y. The equation of the ellipses to which the curve is to be normal at point of cutting is

(48) $b^2(x-a_1)^2 + a^2y^2 = a^2b^2$

in which a_1 is the variable abscissa of the centre. Differentiating

$$\frac{dy}{dx} = -\frac{b^2(x-a_1)}{a^2\ y}$$ or substituting value

of a_1 from (48)

$$\frac{dy}{dx} = \frac{b\sqrt{b^2-y^2}}{ay}$$

This in the formula $1 + \frac{dy}{dx}\ \frac{dy'}{dx'} = \ldots$

gives $\frac{dy'}{dx'} = -\frac{ay}{b\sqrt{b^2-y^2}}$; or, dropping primes, since x and y in the two members refer to the same point,

$$dx = -\frac{b}{a}y^{-1}\,dy\,\sqrt{b^2-y^2}.$$

Whence by integration

$$x = \frac{b}{a}\left\{b\ l_e\sqrt{\frac{b+\sqrt{b^2-y^2}}{b-\sqrt{b^2-y^2}}} - \sqrt{b^2-y^2}\right\} \ldots$$

If we let $x = o$ where $y = b$—*i. e.*, place the centre of the curve at O′—then $c = o$, and

(49)

$$x = \frac{b}{a}\left\{b\ l_e\sqrt{\frac{b+\sqrt{b^2-y^2}}{b-\sqrt{b^2-y^2}}} - \sqrt{b^2-y^2}\right\}$$

This curve is symmetrical about the axes of reference, and is asymptotic to the axis of x.

To obtain (49) in a convenient form for computation, place $y = n\ b$, then

$$(50)\quad x = \frac{b^2}{a}\left\{l_e\sqrt{\frac{1+\sqrt{1-n^2}}{1-\sqrt{1-n^2}}} - \sqrt{1-n^2}\right\}$$

From this equation have been calculated the values of the parenthesis for a series of values of n, as given in the following table.

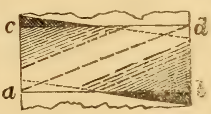
TABLE IV.

Values of n.	Values of $\frac{a\ x}{b^2}$.
0.1	± 2.00[illegible]
0.2	± 1.313
0.3	± [illegible]
0.4	± 0.659
0.5	± 0.450
0.6	± 0.299
0.7	± 0.184
0.8	± 0.093
0.9	± 0.032
1.0	0.000

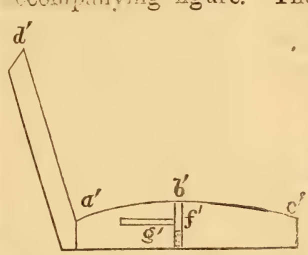
The c j c's on the development of the soffit may be constructed by means of a pattern, one side of which is cut by the curve $k\ O_2\ m$, and the other side is straight and parallel to I X. By placing this pattern upon the curve $k\ O_2\ m$, laying a straight-edge along the back, and then sliding the pattern till it passes through the different points of division on the line $n\ o$, the proper portion of the pattern for each curve will be found. For construction upon a very large scale—as, for instance, upon a platform the true size of the arch—this method would be impracticable. The point of the curve $k\ O_2\ m$ which passes through any point of division on the curve $n\ o$ may then be found by calculation. Find by measurement computation the value of x for the point of division—*i. e.*, its distance from the line D D_2; take this distance as a fractional part of $\pi\ r$—*i. e.*, as a value of n—and, substituting in equation (41), find the corresponding value of y; this will be the constant c of equation (38). Subtracting this from the ordinates found from Table III. will give the ordinates of the curve measured from a line parallel to O_2 X through the point of division. It would also be desirable to determine the exact point in which any c j c cut the curve $D_2 C_3$. We can approximate very closely to this as follows: Find the point as nearly as possible by sketching in the curve from Table III.; through the point thus found draw a parallel to $O_1 X$; find the distance from this parallel to the one drawn through the point of division on *n o* corresponding to the same c j c; add this distance to the value of *c* found as above; take this as the value of *y* in equation (45), and compute from it the corresponding value of *x*; this will be the true abscissa of the curve on the line parallel to $O_1 X$ through the point as first found, and of course will give the intersection of the c j c with the curve $D_2 C_3$ with great accuracy.

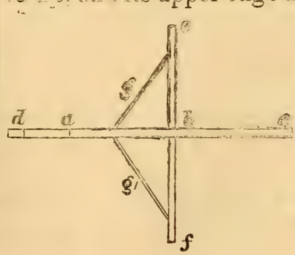
The h j s's are, of course, planes parallel to the P F. The c j s's are a species of conoid generated by a right line moving on the axis of the cylinder as one directrix, a c j c as another, and remaining always perpendicular to the former. Any plane perpendicular to the axis is therefore a plane director. The intersection of any c j s with the P F will be a curve, several points of which will be needed in a construction upon a large scale. These may easily be found by drawing one or more semicircles between $D'V'C_2$ and $B'V'A_2$, finding, by Table III., the curves corresponding to I O L M, for the cylinders of which these semicircles are the vertical projections, and then erecting perpendiculars to the ground line from the points of intersection of these curves with the P F (or planes parallel to it) to meet the semicircles. Projected on a plane parallel to the P F, these curves of intersection of the c j s's with the P F will be normal to the elliptical section cut from the soffit by the P F at the points in which they cut it, and hence will be tangent to the projections on the same plane of the c j c's. All the above remarks apply also to the intersection of a c j s with any h j s—*i. e.*, any plane parallel to the P F.

In order to cut the voussoirs patterns must be made of the cylindrical and plane faces of each. It will also facilitate the operation to construct each in isometric projection, drawing on the cylindrical face one or more elements of the cylinder as guides in the cutting. Cut first the two plane faces of the voussoir precisely parallel to each other; cut roughly another plane face, making an angle with these two approximately equal to that between the P F and a tangent plane to the soffit at some point of the cylindrical face of the voussoir (*i. e.*, to the angle B of equation (51), from which equation its value may be found); lay the stone in such a position that the first two faces shall be vertical, and the third uppermost; apply to the vertical faces the patterns for the ends of the voussoir, with the edges next the soffit uppermost, their relative position being fixed by measurement from the drawings; mark out the ends by the patterns, and also the points where one or more elements of the cylinder pierces the h j s; sink drafts in the upper face connecting these points, and then cut the cylindrical face by a templet cut to the radius of the soffit, and applied at right angles to the elements. Next apply the pattern of the soffit, and draw by it the lines *a b*, *c d*, for the edges of the stone. In the figure *c d* is an element of the cylinder, the stone being seen from above, and being taken from a course near the crown of the arch.



The warped faces can be cut by means of a templet of the form shown in the accompanying figure. The arc *a b c* » *a′ b′ c′* is cut to the radius of the cylinder, and the arm *a d* » *a′d′* is firmly fixed so as to be normal to the arc at the point *a* » *a′*. The cross-bar *e f* is perpendicular to *a b*, and its upper edge also perpendicular to the plane of *a b c* » *a′ b′ c′* and *a d* » *a′ d′*. *g* » *g′* and *g g′* are braces. Suppose the stone were cut, then, if the curved edge of the templet





were applied to the cylindrical face with the edge of cross-bar *e x* coinciding with an element of the cylinder, and the point *a* » *a'* at the edge of the voussoir, the edge *a d* » *a' d'* of the normal arm would lie upon the warped face, and coincide with an element of it. If a number of drafts be sunk in the stone, then, by means of this templet, the warped faces can be easily cut. It only remains to cut the Ex s of the voussoir. If this surface is to be a cylinder concentric with the soffit, the intersections of this cylinder with the c j s's can be at once laid off on the stone by the aid of the templet. Measure on *a d* » *a' d'* from *a'* » *a'* the distance *r*—*r*, between soffit and Ex s; mark the point, and, applying the templet as described above, mark on the stone any number of points in the required curve. If the arch is to be built upon with stone, it would be better to cut the Ex s in steps, each stone having one or more horizontal and vertical plane faces when in position in the arch. This would not add to the difficulty of *cutting* the stones, though it would somewhat to that of making the drawings. This way of cutting the stones is shown in the drawing of the arch according to the "cow's horn" method.

The diedral angle at the edge of a voussoir must not be less than a certain limit, otherwise the stone will be deficient in strength at this edge. The limit is usually taken at 60°; hence it follows that a *full centred* arch should not be constructed by this method with a greater obliquity than 60°; but, as the angle between a tangent plane to the soffit and the P F *increases* as the element of contact is taken higher above the springing plane, up to 90° at the crown, it is evident that a *segmental* arch may be built with a greater obliquity than 60°, whose diedral angles will be within the limits. To find the chord of the segment (*i. e.*, the span),

Let α = C_2 D_2 D' = obliquity of arch.

Let β = angle between P F and tangent plane to soffit; *i. e.*, its limiting angle.

Let γ = angle between the tangent plane to soffit and the H P.

Then we have a right-angled spherical triangle, and by spherical trigonometry,

$$\cos\beta = \cos\alpha \sin\gamma$$

$$\text{or } \sin\gamma = \frac{\cos\beta}{\cos\alpha},$$

$$(51)\quad \therefore \text{Span} = \frac{2\,r \sin\gamma = 2\,r\cos\beta}{\cos\alpha}$$

If we let $\beta = 60°$, then $\cos\beta = \frac{1}{2}$;

$$\therefore \text{ Span} = \frac{r}{\cos\alpha} = r \text{ secant } \alpha.$$

Also $\cos\alpha = \frac{r}{\text{span}}$ from which we can determine the limit of obliquity for a given segment.

If the span $= r$, then $\cos\alpha = 1$, and $\alpha = o$. Therefore we may give any obliquity to the arch that we please without passing the limit. If $\alpha = 30°$, the limiting span is

$$\text{Span} = \frac{2\,r}{\sqrt{3}} = 1.1546\,r.$$

The security of the arch constructed after this method will next be considered. In Fig. 2 the curves Q P' *a* and Q P_1' *b* are the vertical projections of the curves cut from the c j s, whose directrices are the axis of the arch, O Q, and the curve K O P_1 by the planes P *c* and P_1 O_1. These curves will be shown to have maximum points at P P' and P_1 P' where they pierce the soffit. *h* K O L *g* is the horizontal projection of the curve cut from the same c j s by the horizontal plane *e f*, and it will be shown that its tangent at the point of piercing the soffit is perpendicular to the P F. It will likewise be shown that the tangent plane to the c j s at any point of the c j c is perpendicular to the tangent to the elliptical section parallel to the P F at that point. Hence, where it intersects the soffit every c j s is exactly normal to that direction which we have assumed to be the direction of the pressure.

First to obtain the equation of a c j s. Let the line O X be the axis of *x*, the line Z O Q the axis of *z*; then let the axis of *y* be a vertical line through O. Then the equations of the curve K O P P_1 will be

$$(a)\qquad x^2 + y^2 = r^2$$

$$(b)\qquad z = \frac{r^2}{h}\, l_e\left(\frac{r-x}{r+x}\right).$$

Equation (b) is derived from equation (44) by substituting z for y and changing the sign of the right hand number, because the axis O Q in equation (44) was considered as positive from O toward Q, while now it is taken as positive from O toward z.

Let $\frac{h}{r^2} = c$, and solve equation (b) for x.

$$\therefore e^{cz} = \frac{r - x}{r + x}; \text{ whence}$$

$$(52) \qquad x = r\,\frac{1 - e^{cz}}{1 + e^{cz}}$$

For the point x, we have

$$(53) \qquad x_1 = r \cdot \frac{1 - e^{cz_1}}{1 + e^{cz_1}}$$

Substitute value of x_1 from (53) in (a).

$$\therefore y_1^2 = r^2 - r^2 \cdot \frac{1 - 2e^{cz_1} + e^{2cz_1}}{1 + 2e^{cz_1} + e^{2cz_1}}$$

$$= r^2\left(\frac{1 + 2e^{cz_1} + e^{2cz_1} - 1 + 2e^{cz_1} - e^{2cz_1}}{(1 + e^{cz_1})^2}\right)$$

$$(54) \qquad \therefore y_1 = \frac{2r\sqrt{e^{cz_1}}}{1 + e^{cz_1}}$$

The equation of a line in X Y through the points $(x_1\, y_1)$ and $(x_2\, y_2)$ is

$$(55) \qquad \frac{y - y_2}{x - x_2} = \frac{y_1 - y_2}{x_1 - x_2}.$$

Since O Q is a directrix of the surface, we shall have

$$(56) \qquad x_2 = y_2 = o$$

$\therefore$ substituting from (53), (54), and (56) in (55)

$$\frac{y}{x} = \frac{2r\sqrt{e^{cz_1}}}{1 + e^{cz_1}} \cdot \frac{1 + e^{cz_1}}{r\,(1 - e^{cz_1})};$$

or reducing and making z_1 general by dropping the subscript,

$$(57) \qquad \frac{y}{x} = \frac{2\,e^{\frac{cz}{2}}}{1 - e^{cz}} = \frac{2\,e^{\frac{hz}{2r^2}}}{1 - e^{\frac{hz}{r^2}}},$$

which is the equation of a c j s.

Intersect this surface by the vertical plane P c d, whose equation is

$$(58) \qquad z = \frac{2r}{h}(a_1 - x),$$

in which $a_1 = \text{O } c =$ intercept on X, and $\frac{2r}{h} = \tan\alpha$.

Substituting value of z from (58) in (57),

$$(59) \qquad \frac{y}{x} = \frac{2\,e^{\frac{a_1 - x}{r}}}{1 - e^{\frac{2(a_1 - x)}{r}}} = \frac{2\,e^u}{1 - e^{2u}}$$

if we let $u = \frac{a_1 - x}{r}$.

This is the equation of the curves Q P′ a, Q P_1' b, etc. In (59) if $x = a_1$, $y = \infty$; $\therefore$ the line $x = a_1$ is an asymptote. Also if $x = o$, $y = o$, and if $x = \pm\infty$, $y = o$, and the axis of x is an asymptote.

Differentiating (59)

$$\frac{dy}{dx} = \frac{2(1 - e^{2u})\left(e^u + xe_u\left(\frac{du}{dx}\right)\right) + 4\,e^{3u}\,x\left(\frac{du}{dx}\right)}{(1 - e^{2u})^2}$$

But $\frac{du}{dx} = -\frac{1}{r}$, therefore after reduction

$$(60) \qquad \frac{dy}{dx} = 2\,e^u\left\{\frac{r - x - (r + x)e^{2u}}{r\,(1 - e^{2u})^2}\right\}$$

For a maximum $\frac{dy}{dx} = o$;]

$$\therefore \quad r - x - (r + x)\,e^{2u} = o.$$

$$(61) \qquad e^{2u} = \frac{r - x}{r + x};$$

This equation gives the values of x for which y is a maximum.

Now eliminate y between equations (59) and (a),

$$\therefore \quad x^2 + \frac{4\,e^{2u}\,x^2}{(1 - e^{2u})^2} = r^2; \text{ whence}$$

$x^2\left(\frac{1 + e^{2u}}{1 - e^{2u}}\right)^2 = r^2$; therefore solving for e^{2u},

$$(61') \qquad e^{2u} = \frac{r - x}{r + x}.$$

This equation, which gives the x co-ordinate of the point of intersection of the curves Q P′ a, Q P′ b, etc., with the circle D′ V C_2, is identical with (61), which gives x where y is a maximum; therefore the curve whose equations are

$$\begin{cases} y = \dfrac{2\, e^u x}{1 - e^{2u}} \\ z = \dfrac{2\, r}{h}(a_1 - x) \end{cases}$$

has its tangent line horizontal at the point of piercing the soffit.

To find the inclination of the tangent at the point where the curve pierces a cylinder concentric with the soffit whose radius is r_1. If the co-ordinates of this point be $x_1\, y_1$ we have by substituting in (61′), u_1 for u, r_1 for r, and x_1 for x,

$$e^{2u_1} = \frac{r_1 - x_1}{r_1 + x_1}; \quad \therefore e^{u_1} = \sqrt{\frac{r_1 - x_1}{r_1 + x_1}}.$$

Substituting these values in (60),

$$\frac{dy_1}{dx_1} = \frac{2}{r}\sqrt{\frac{r_1 - x_1}{r_1 + x_1}} \left\{ \frac{r - x_1 - (r + x_1)\dfrac{r_1 - x_1}{r_1 + x_1}}{\left(1 - \dfrac{r_1 - x_1}{r_1 + x_1}\right)^2} \right\}$$

whence by reduction,

$$(62) \quad \frac{dy_1}{dx_1} = \frac{(r - r_1)\sqrt{r_1^2 - x_1^2}}{r\, x_1} = -\frac{\delta y_1}{r\, x_1},$$

if we let $r_1 - r = \delta$.

If we multiply $\frac{dy_1}{dx_1}$ by $\cos\alpha$, we obtain the tangent of the angle between the tangent line to the curves c P » Q P′a, O_1 P_1 » Q P_1′b, etc., at the point of piercing the Ex s and the H P. Call this angle t, then

$$(63) \qquad \tan t = -\frac{\delta y_1 \cos\alpha}{r\, x_1}.$$

Suppose $\alpha = 60°$, $\frac{\delta}{r} = \frac{2}{15}$, then

If $x_1 = r_1 \cos 10°$, $y_1 = r_1 \sin 10°$, and $t = 0°\ 40'\ 20''$

" $x_1 = r_1 \cos 20°$, $y_1 = r_1 \sin 20°$, and $t = 1°\ 23'\ 20''$

" $x_1 = r_1 \cos 30°$, $y_1 = r_1 \sin 30°$, and $t = 2°\ 12'\ 15''$

Intersect the locus of equation (57) by the plane

$$y = b;$$

$$\therefore \quad \frac{b}{x} = \frac{2\, e^{\frac{cz}{2}}}{1 - e^{cz}};$$

$$\therefore b\, e^{cz} + 2\, x\, e^{\frac{cz}{2}} - b = o;$$

solving this for $e^{\frac{cz}{2}}$ as a quadratic,

$$e^{\frac{cz}{2}} = \frac{-x \pm \sqrt{x^2 + b^2}}{b}$$

$$(64) \quad \therefore z = \frac{2}{c}\, l_e \left(\frac{-x \pm \sqrt{x^2 + b^2}}{b}\right).$$

Differentiating and reducing,

$$(65) \quad \frac{dz}{dx} = \frac{2}{\mp c\sqrt{x^2 + b^2}} = \frac{2\, r^2}{\mp h\sqrt{x^2 + b^2}}$$

When $x = o$, $\frac{dz_o}{dx_o} = \mp\frac{2r^2}{b\, h} = \mp\frac{r}{b}\tan\alpha.$

" $b = r_1$ and $x = o$, $\frac{dz_{or_1}}{dx_{or_1}} = \frac{2r}{h}\cdot\frac{r}{r_1} = \frac{r}{r_1}\tan\alpha$

To find the angle at which the locus of (64) pierces a cylinder concentric with the soffit, eliminate y between $y = b$ and $x^2 + y^2 = r_1^2$.

$$\therefore \quad x_1^2 = r_1^2 - b^2.$$

Substitute this value of x in (65),

(66)

$$\therefore \frac{dz_1}{dx_1} = \frac{2\, r^2}{\mp h\sqrt{r_1^2 - b^2 + b^2}} = \mp\frac{2\, r}{h}\cdot\frac{r}{r_1} = \frac{r}{r_1}\tan\alpha$$

If $r_1 = r$, $\frac{dz_1}{dx_1} = \tan\alpha$. We see therefore that the locus of (64) pierces the soffit at the angle α.—*i. e.*, its tangent is there perpendicular to the P F—and that it pierces any cylinder concentric with the soffit at a constant angle for any given value of α, no matter what value b may have.

The surface is thus seen to differ very essentially from the helicoid previously considered, as regards tendency to sliding on the coursing joints, as is indeed evident from a comparison of the two drawings.

The tangent plane to the c j s at any point of the c j c, as P P′, must contain the element of the surface through the point and the tangent line at the point to the curve cut out by a horizontal plane through the point; therefore it must be perpendicular to the P F. The tang. of the angle between it and the H P will be equal to

(67) $\tan {}'PQC_2 \operatorname{cosec} \alpha = \tan N$

if N be the angle between the normal at P P′ and a vertical line; but this is also the expression for the tangent of the angle between a vertical line and the tangent line at P P′ to the elliptical section of the soffit parallel to the P F; therefore the assumed direction of pressure is normal to the c j s at any point of the c j c. This result might have been predicted from the mode of construction of the c j c's.

The curve cut from a c j s by the plane

(68) $$z = \frac{h}{2r}(x - a_1)$$

parallel to the P F is always convex towards the springing plane between the soffit and Ex s. Its equation found by substitution in (57) is

(69) $$\frac{y}{x} = \frac{2\, e^{\frac{h\,2}{4\,r3}(x-a')}}{1-e^{\frac{h\,2}{2\,r3}(x-a')}} = \frac{2\, e^v}{1 - e^{2v}}$$

if we place $\frac{h^2}{4\,r^3}(x - a_1) = v$.

By differentiation and reduction we obtain, in the same way in which we found (62),

(70) $$\frac{dy_1}{dx_1} = \frac{y_1}{x_1}\left(\frac{4\,r^3 + h^2\,r_1}{4\,r^3}\right),$$

which is the tangent of the angle between the tangent line to the locus of (69) at point of piercing the cylinder whose radius is r_1 and the horizontal plane. To obtain the angle between the tangent line to the curve in space whose equations are (68) and (69) and the H P, multiply (70) by $\sin \alpha = \frac{2r}{\sqrt{h^2 + 4\,r^2}}$

Call this angle t_1, then

(71) $$\tan t_1 = \frac{y_1}{x_1}\left(\frac{4\,r^3 + h^2\,r_1}{2\,r^2\,\sqrt{h^2 + 4\,r^2}}\right) = \frac{y_1}{x_1} \cdot \frac{r\,\sin^2 a + r_1 \cos^2 \alpha}{r \sin \alpha}$$

If $r_1 = r$, which gives the point of piercing the soffit,

(72) $$\tan t_s = \frac{y_1}{x_1} \cdot \frac{\sqrt{4\,r^2 + h^2}}{2\,r} = \frac{y_1}{x_1} \operatorname{cosec} \alpha,$$

which is identical with equation (67).

If $\frac{r_1}{r} = \frac{17}{15}$, and $\alpha = 60°$, then

when $\frac{y_1}{x_1} = \tan 10°$, $t_1 = 11° 52' 50''$, $t_s = 11° 30' 30''$

" $\frac{y_1}{x_1} = \tan 20°$, $t_1 = 23° 28' 16''$, $t_s = 22° 47' 45''$

" $\frac{y_1}{x_1} = \tan 30°$, $t_1 = 34° 33' 30''$, $t_s = 33° 41' 24''$

The points for which t_1 and t_s are found being on the same radius are of course on different curves, though these curves are so near together that the difference between the angles t_1 and t_s is very nearly the same as the difference between the slope of the tangents to a single curve at the points of piercing the soffit and Ex s.

The function $n = t_1 - t_s$ is found by differentiation to be a maximum when

$$\frac{y_1}{x_1} = \frac{1}{\sqrt{\sin^2 \alpha + \frac{r_1}{r} \cos^2}} = \tan 44° 32'$$

where α and $\frac{r_1}{r}$ have the values assigned above. The maximum value of the function in this case is $t_1 - t_s = 55' 31''$.

It appears, therefore, that at *no* point on the c j s, between the soffit and the Ex s does the normal to the c j s vary to any extent from the assumed direction of pressure.

Wool waste is, on account of the large proportion of nitrogen it contains (in pure wool this reaches 16 or 17 per cent.), an excellent manure; but there is this disadvantage about it, that it has to lie 3 or 4 years in the ground before it is decomposed. M. Ladureau, of Tourcoing, has sought to obviate this by heating the waste to 120 or 140 C., whereby a reddish, friable, and easily pulverized product is obtained, having a weak smell of chicory and burnt wool. The waste thus treated, being deprived of water, thereby loses from 10 to 15 per cent. of its weight, but sustains no loss of nitrogen, if the operation is carefully done. The product, with a guaranteed proportion of 6 to 8 per cent. nitrogen, is sold at 13 fr. per 100 kilogrammes; and numerous recent trials of it are said to have given very satisfactory results.—*English Mechanic.*

AMERICAN V. ENGLISH BRIDGES.

From "The Engineer."

Recently some slight controversy arose between well-known authorities, on both sides of the Atlantic, with respect to the relative merits of the two methods or systems of bridge construction practised in England and the United States. At the present, and for some time past, there has been a general and gradually increasing tendency on the part of American engineers, not only to replace old, worn-out, incompetent timber bridges by others of iron, but also to erect original structures of the latter material. No doubt necessity as well as freewill has contributed to this result. But, inasmuch as there is no question that the employment of iron in this capacity has now received an acknowledged stimulus in America, it is a fitting opportunity to make a brief comparison between the two methods of bridge building alluded to. Into this comparison iron bridges alone enter. Structures of timber, however skilfully designed and excellently constructed, cannot be regarded in any other light than that of temporary engineering expedients, doomed inevitably in the course of time, either through their own weakness or incapacity to fulfil the increasing duties demanded of them, to be superseded by those of a more stable and permanent character. The employment of timber bridges in the States, or any new country similarly circumstanced, is not only justifiable but commendable. It is true that we, with all the resources of an old and civilized nation at our command, may smile at the idea of a railway bridge over which the train must crawl almost at a snail's pace, but it must be borne in mind that without that bridge the train could not cross the intervening space at all. In one sense, the object, which is to establish communication for goods and passengers from abutment to abutment, is as adequately accomplished as if the bridge allowed of the passage of the "limited mail" or the "Scotch express." It is in every instance the duty of an engineer to effect the desired purpose by the means at his command, and the fewer and the more imperfect those means are, the greater is the credit due to him when his efforts are crowned with success.

To revert, however, to our more immediate subject. One of the points of superiority claimed by American engineers in their bridges is their greater depth; or, more correctly speaking, the greater ratio of the depth to the span. This is incontestable, but while admitting thus much, we do not intend giving our transatlantic brethren more credit than they deserve. A little inquiry will, we think, discover the reason, or partly the reason, why we are only now, as it were, becoming aware of the economy of deep open web or trussed girders, and why they adopted them contemporaneously with the introduction of those structures of iron in their country. The type of girder first and very extensively used by our engineers for railway bridges, was the plate, or solid continuous web, whether in the box, tubular, or single plate form. All girders of this type are shallow in comparison with those of a trussed description, the ratio of depth to span ranging from about one-twelfth to one-sixteenth—in some instances to one-eighteenth. The necessity for adhering to a comparatively shallow depth in the case of solid or continuous web girders arises from the fact that any increase in that dimension is attended with so large a corresponding increase in the weight of the web itself and the accompanying stiffening irons and wrappers, as to practically nullify the advantages arising from the same cause so far as the theoretical strength of the girder is concerned. Moreover, except in large examples, a continuous web must be thicker than required by theory; that is, its sectional area must be in excess of that which is demanded by the strain upon it, which is another reason for the adoption of a minimum depth. Consequently, when a new form of girder was introduced, with the particular merits and the correct proportions of which our engineers were not well acquainted, it is not difficult to understand how, while adopting the new girder, they gave it, and for a long time continued to give it, the relative proportions and dimensions of its predecessor. Thus, in fact, we find that the majority of the early open web and lattice girders have a ratio of depth to span of about one-twelfth. As the particular features of the trussed girder became more manifest, and the whole design better understood, it was found that an increase in the depth within certain limits was not attended with the practical disadvantages belonging to the solid-sided form. Hence the ratio was increased. On the other hand, the American engineers were always accustomed not only to the trussed form of girder, but to those whose depth is comparatively very large. From one-eighth to one-tenth was a common ratio of depth to span of their large timber railway bridges. In changing the material of these structures they adhered to the same proportions, and, in fact, followed the same line of argument as our own engineers, although it led in their case to a more accurate conclusion. While admitting the economy of deep trussed girders, it must not be assumed that there is no limit to that dimension. Trussed girders must be laterally stiffened with respect to their webs, as well as those of the plate form, and this can be accomplished in long, compressive members only at a sacrifice. Summing up this part of the question, it is probable that the American engineers err as much in the one extreme as we do in the other.

For several reasons, we shall not enter deeply into the much-mooted point whether pins or rivets constitute the better mode of connecting the web and flanges of a trussed girder. As a crushing argument against the use of pins, the advocates for that of rivets invariably adduce the case of the well-known Crumline Viaduct, in which, after some years of traffic, the pin joints became loosened. The pins were then removed, gusset plates placed over the joints, and the whole riveted together. Although it is undeniable that until the advocates for the use of pins can point to a similar instance in which rivet joints have been removed and pins substituted for them, the advantage will always remain with the partisans of the rivets, yet we do not attach quite so much importance to this individual case as many do. It should be borne in mind that this Crumline Viaduct is one of the early examples of the Warren truss, and it is quite possible that the proportions of the pins and eyes may not have been quite correct. Again, the workmanship may not have been quite so good as it ought to have been. Not that this is our opinion, but these assumptions may be made by those who prefer pins to rivets. On the other hand, we know that among the thousand examples of girders in the construction of which rivets are employed, some are undoubtedly of very inferior workmanship and very unskilfully designed. Nevertheless, the substitution of the one method of connection for the other has not taken place, as in the instance brought forward. That pinned girders —if we may use the term in contradistinction to riveted—are put together with greater facility and rapidity in countries in which skilled labor is both expensive and scarce must be admitted, although this advantage has been very much overrated. But there lies all the superiority which the one system can claim over the other. It will be conceded that, no matter how accurate the proportions, how tight fitting the pins, and how excellent the workmanship, there is the possibility of motion among the several parts of a connection so formed. Will not the agents time and use convert this possibility into a certainty? In other words, the connections of a pinned girder depend not so much upon the soundness of the principle adopted as upon the degree of excellence to which the workmanship attains. Will the time ever arrive when we shall hear the Charing Cross bridge rattle as the trains cross over it, owing to the pins loosening?

Another important distinction between the American and English—that is, between the pinned and riveted systems of bridge construction—is that the effect of the former is to concentrate or localize the strains upon certain points of the structure; whereas the tendency of the latter is to distribute them as uniformly as possible over the whole girder. It is quite unnecessary to allude to the obvious superiority both in theory and practice of the latter system. So far as the web is concerned, in moderately long girders, not exceeding 100 ft., particularly if the live load be light, there is an advantage in reducing the number of bars in the web, or what amounts to the same, in employing the Warren instead of the lattice girder. But, on the other hand, the flanges suffer. The comparatively long interval at which the flanges are supported tends to induce a bending strain upon the centre of that part of the flanges between the apices of the triangles, which in many examples which have come under our notice must be very appreciable. It is obvious that since for certain lengths the flanges are of uniform sectional area, those portions in the immediate contiguity of the intersections of the web, or the apices of the triangles, must be more severely strained than those situated in the centre between two apices. When the distance between any two apices is 12 ft. or 15 ft., as frequently occurs, whatever advantage may be gained by the web is undoubtedly lost in the flanges. It is this which puts a limit to the span of Warren girders, independently of the fact that whenever any bending action is induced in any component members of a trussed girder, the very principle of its design is at once entrenched upon. The action of the strains is no longer confined to simple thrusts and pulls in the direction of the length of the several parts, and the economy of the design is seriously impaired. It is quite possible to construct a pair of deep, light, rickety girders, and brace them together so that they will constitute a [illegible] stiff and steady structure [illegible], but if the quantity of material [illegible] for the bracing be taken into account, it will be found that it would have been almost equally economical to build good strong stiff girders in the first place. In this case very light bracing would suffice, and the bridge would be [illegible] strong. Girders which possess in themselves their proper amount of rigidity, will require, when of definite proportions, bracing to maintain them in form; but rickety girders will require bracing to force them into form. In making comparisons of the cost of bridges constructed on different principles, nothing is more common than to take the girders separately as an example of the whole structure, and neglect the bracing altogether. Obviously this tells enormously in favor of the rickety style of bridge building.

It has been claimed for the pinned girder, that insomuch as it exposes less surface to the weather, so will it suffer less, and consequently be cheaper to paint. Certainly, if one bar of a scantling of 3 in. by $1\frac{1}{2}$ in. be substituted for three bars, each of 3 in. by $\frac{1}{2}$ in., the surface exposed in the one case will be only one third of that in the other. Thus there will be a gain so far as the web may be considered, but the reverse will occur in the flanges. All pinned girders require deep vertical plates in the flanges, which in the riveted girders can be used more advantageously in a horizontal position. Two or more plates riveted together longitudinally present the same surface to exposure as one, neglecting the thickness, but this is not the case with a vertical plate, which is exposed on both surfaces. The question may be well asked, Shall we ever adopt the pinned girder, or will the Americans adopt the riveted girder? In answer to this there is one very significant fact, that the pinned girder is losing ground with our engineers, even when the bridge is designed for a country where that method of connection was much used, and for which it is well adapted. At the present moment there are no less than sixty-four spans of Warren girders being built for a magnificent Indian river bridge, in which pins are discarded and rivets employed for the connections of the web and flanges. Again the pin has been superseded by the rivet in the suspension principle. The suspending bars in the Albert bridge over the Thames at Chelsea are not connected by pins, but by rivets. This furnishes another proof that the rigid method of connection is far superior to any other which, even theoretically, allows motion between the connecting parts.

Mr. C. F[illegible], of Fulham, England, has patented a process for mixing slacks of various coals, coke or other carbonaceous materials, with Portland or other hydraulic cements in suitable manner and proportion. Also for treating artificial fuels with coal tar, common pitch, or asphalts.

EUROPEAN RAILWAY CONSTRUCTION SINCE 1850.

From the "Iron Age."

FROM a statistical statement just published by the English Board of Trade, showing the length of railway constructed in the various States of the world between the years 1850 and 1872, Herapath's *Railway Journal* presents an abstract, from which we compile: Commencing with the

United Kingdom. In 1850 the length constructed amounted to 6,621 miles, increasing in 1855 to 8,280 miles, reaching 10,433 miles in 1860, and 13,289 miles in 1865, when the increase up to 1870 becomes more moderate, being a total of 15,537, and in 1872 reaching a total of 15,814 miles. These figures show the steady growth of the railway system in a country where capital is abundant and joint stock enterprise is unhampered by State interference.

In France the development of railways under the Companies' system is remarkable. In 1850 there were only 1,689 miles constructed by companies, and 209 by the State, after which period the State ceased construction, and the total mileage constructed rose to 3,434 in 1855, advanced to 5,[illegible]58 in 1860, increased to 8,439 in 1865, and reached 10,[illegible]47 in 1870; the increase between the two latter periods being greater than that of the United Kingdom. The seven States comprising the present

German Empire have been very progressive in railway construction, and here, with the exception of Prussia, the State since 1860 appears to have gone ahead of the companies, especially during the five years preceding the Franco-German war, in which the State alone constructed nearly 2,000 additional miles of railway, and the companies over 1,000 miles. As might be anticipated, Prussia takes the lead. In 1850 the State possessed but 1,776 miles of railway, 1,190 miles being made by the companies. In 1872 the total mileage of the Prussian railways reached 8,646, and of this 4,7[illegible]3 miles, or over 50 per cent., were in the hands of the companies. The railway mileage of total Germany in 1872 was 12,701, 7,619 of which were State and 5,082 companies' lines. The Prussian thus represents more than two-thirds of the entire railway system of Germany.

Russia, since 1865 has been making some progress in railway extension, and like her neighbor Austria, very wisely gives the preference to companies over State construction, having increased the mileage of companies' lines from 1,773 miles in 1865 to 6,572 miles in 1870, having only 399 miles of State railway in that year, making a total of 6,971 miles of railway, a very small matter for so vast an empire. The returns before us, however, do not include the additional extensions constructed since 1870.

Austria, since 1860, has not been inactive in railway construction, having increased her mileage from 1,788 miles in 1860, to 2,231, in 1865, reaching 3,724 in 1870, while Hungary keeps pace with the empire by making over 1,100 miles of railway between 1860 and 1870.

Spain and Portugal.—In Spain the effects of disruption and civil war are clearly apparent in the fact that within the five years ending in 1870 but 398 miles of railway have been opened, while in the five years preceding 1865 there were 1,791 miles constructed by private companies. Portugal exhibits but little activity in railway making, the country being no doubt an unpromising one in an engineering point of view.

Italy exhibits a striking contrast to Spain in the rapid strides she has made in opening up the country by railways, having advanced the mileage of her completed railways in the ten years ending 1870 from 1,1[illegible]7 to 3,855 miles, while in the last two years ending 1872 the total length constructed by private companies in Italy (including Rome) amounted to 4,087.

In Holland and Belgium, where the State appears desirous of acquiring the ownership of the railways, but few additional lines have been made since 1870, the increased mileage between 1865 and 1872 being nearly equal in both States. The total length constructed in the former State up to 1872 was 1,043 against 560 miles in 1865 and in the latter 2,004 in 1872, against 1,418 miles in 1865.

Miscellaneous.—In the Northern States of Sweden and Norway the total open mileage has increased in the former from 956 miles in 1865 to 1,198 in 1872, and in Norway from 168 miles in 1865 to 307 in 1872. During the same period Switzerland constructed 137 miles of additional railway, making the total length of Swiss railways up to 1872, 913 miles. Denmark shows a total mileage of 540 miles up to 1872, while Turkey had only constructed by companies a total length of 152 miles of railway up to 1870, and the unprogressive kingdom of Greece winds up the list of European railways with a total of 6 miles. According to this return the total length of European railways in 1865, constructed by private companies, amounted to 39,626 miles, and those constructed by the States to 7,013, making a total of 46,639 miles.

In the United States of America the total length of railways constructed was in 1850, 9,022 miles; in 1855 the mileage increased to 18,454; in 1860 it had risen to 30,634. In 1865 it rose to 35,085, and in 1870 it reached the total amount of 53,399 miles, thus in ten years nearly doubling the lines constructed.

THE NARROW GAUGE IN SWITZERLAND.

From "Engineering."

This season has been marked by an event of considerable importance in the dominion of our railways. I allude to the completion and opening of the first Swiss narrow-gauge railway. Here, like in other countries, railways on a narrower gauge than that of our 4 ft. 8½ in. standard, have been vehemently attacked, both by argument and dogmatically, by engineers devoted to established practice; but, on the other hand, the necessity of cheap branch lines, which could be worked with economy, presented itself with so much urgency that the narrow-gauge system became finally a *fait accompli*, and its future development is but a matter of time, required to extend a knowledge of the sound principles upon which such railways are in fact constructed.

The narrow-gauge line from Lausanne (on Lake Geneva) to Echallens, which was opened last June, has but a length of 15 kilometres or, say 9½ miles, and is built to a gauge of 1 metre. This same gauge—being also that of your new Indian State railways—has been adopted for all the other smaller lines either building or projected in Switzerland, to which I shall refer hereafter.

The following are the characteristic points in connection with the construction and equipment of the Lausanne line. In the first place, this railway has been traced out partly upon the existing country road, presenting thus a very close adaptation of grade to the natural surface, with maximum inclines of 1 in 25, and smallest curves of about three chains radius. The Vignoles rails have been acquired at a low price from the Fell Mont-Cenis line; but their weight of 58 lbs. is on this account considerably in excess of the requirements of the case, as a 40-lb. rail would have been ample. The cross-sleepers of larch wood are 5 ft. long by 6½ in. by 4¾ in.; they are placed at distances of 3 ft. 10 in. and 2 ft. apart at the joints. The ballast is laid 6½ ft. wide and 7 in. below the bottom of the ties. The rolling stock of this little line, consisting of two locomotives, twelve passenger carriages, five luggage vans, and twenty-one goods wagons, have likewise been obtained from the liquidation of the Mont-Cenis line; this stock, however, before it could be employed at Lausanne, had to be first delivered of the mid-rail gear, and second, its gauge had to be reduced by 4⅝ in., this being the difference between the former Mont-Cenis gauge and that of one metre. Subsequently the two engines—the first by which the Fell railway was worked—were found wholly defective, and in consequence two small four-wheeled tank engines, weighing eight tons in working trim, were bought at the Creusot works; these lilliputian engines now working the line exclusively.

The total cost of the line, including rolling stock, has been 78,000 francs per kilometre, or say £5,000 per mile. As far then as economy is concerned, this result is very satisfactory (our railways of the normal gauge have cost on the average four times as much), but the fact that the line was equipped with an old permanent way and rolling stock points clearly out that the present example cannot be considered as a type representing fairly modern narrow-gauge practice.

The second Swiss narrow-gauge enterprise, still more characteristic than the one described, although of smaller extent, is situated almost on the very top of the celebrated Righi, forming as it were but another link in those mighty chains that are to lay the queen of the mountains in irons. The Righi narrow-gauge road is about three miles in length, connecting the Kaltbad station with that of the Scheideck. The gauge is likewise one metre, and the maximum gradients, worked by adhesion, are 1 in 20. The six-wheeled coupled tank engines of 20 tons weight (built at the new Swiss locomotive works) present no peculiar features, with the exception of the boiler, which is wholly cylindrical and constructed on a plan adopted once by Mr. Ramsbottom in some shunting engines. The long open passenger carriages are carried on two four-wheeled bogies and can accommodate 55 passengers, disposed on eleven parallel benches, to which access is gained by an equal number of side doors. Of course this line serves only tourist purposes during the summer months, and will be ready for use next season.

The other narrow-gauge lines, either building or projected in this country, are for their greater portion the property of the Swiss Society for Narrow-Gauge Railways, a company founded two years ago by Dr. Dubs, late President of the Confederation. I hope to be able to forward you, shortly, drawings illustrative of this company's rolling stock, &c., which has been designed with much care, and with the utmost attention to the comfort of the travelling public. For the present I annex a statement of our narrow guage pursuits, which now stands as follows:

		Kilometres.
Lines of one metre gauge	opened	15
" "	building	93
" "	projected	130
Being a total of		238

or about 148 miles of narrow-gauge railways.

A. Brunner,
Inspector of Rolling Stock of the Swiss Railways.

HEAT ABSORBED BY EXPANSION.

By H. S. Carhart, A. M., Professor of Physics, Northwestern University.

Written for Van Nostrand's Magazine.

The statement is sometimes made that mere expansion, without the performance of external work, such as forcing aside the atmosphere, does not cool the expanding gas. See an article on "The Mechanical Equivalent of the Heat Unit" in the January Eclectic; also, Tyndall's "Heat as a Mode of Motion," page 71. The assertion is one not justified certainly by experiment. Let us put it to the test.

We will screw a copper condensing chamber upon the plate of our air-pump and examine its temperature by means of a sensitive thermopile and astatic needle, the movements of the needle being greatly magnified by projecting its image on a screen by means of our Wale & Co's oxy-hydrogen lantern. Let us first assure ourselves that the temperature of the chamber is the same as the face of the pile. This is the case, for the needle stands at zero. The chamber is now quickly exhausted of air, and the face of the pile again applied. Our magnified image of the pointer connected with the needle moves promptly across the screen, showing conclusively that the chamber is perceptibly cooler than before. While the pump was working, the expanding air was sufficiently chilled to lower also the temperature of the copper vessel.

Here the refrigeration cannot be ascribed to *external* work, for we have accomplished that ourselves by working the pump. The air has "expanded into a vacuum," exactly as the author of the article referred to would have the experiment performed, the vacuum being produced at every stroke in the pump barrel. And yet the air has been cooled.

But let us vary the experiment so as to lessen the probability of error by a difference of procedure. We so arrange our lantern that a strong beam of light passes through a clear glass receiver on the pump plate. Some light is reflected from the sides of the receiver, but the beam does not mark its way through the interior. In order to insure the presence of a sufficient quantity of vapor of water we will place a beaker of warm water under the receiver for a few seconds. The apparatus being now all arranged, let the attention be directed to the receiver, while we work the pump. The first *quarter of a stroke* is followed by the sudden appearance of a white shaft of light tracking its way through the receiver. Watch the curling cloud, for this it is, as it settles down. Gradually it disappears, but another quarter of a stroke is sufficient to reproduce the beautiful effect. Every minute globule of water reflects to us its quota of light, and by placing our eye in the proper position we discover that the shaft of light is even adorned with the colors of the rainbow. How shall we account for the formation of this cloud except that by expansion the air has been cooled and a part of the vapor of water has in consequence been condensed? Yet no external work has been done in pushing back the outside air, for we have again accomplished that by muscular force.

But if expansion produces cold, clearly heat has been absorbed in doing some kind of internal work, since by the conditions of the experiment it has not been allowed to do external work. What is this internal work? When the air expands its molecules are set in motion, and *some* force must be expended in overcoming their inertia. The force that is called upon to perform this work is evidently the repulsion between the molecules of air. But repulsion in this case owes its existence and intensity to that molecular oscillation which we call heat. Hence, when repulsion does work in setting the particles of air in motion and overcoming their inertia it does so at the expense of the heat of the air, since this is its only base of supplies.

In the *Bulletin* of the Belgian Academy of Sciences (Nos. 9 and 10) M. Melsens communicates a third note on lightning conductors; in this he first shows how a lightning rod, in good condition, and made according to "classical" instructions, failed to completely protect a building fitted with it. The phenomenon seem to point to the inutility of lightning rods with points and multiple conductors. In the second part, he suggests practical means for control and verification of lightning conductors, commending the joint use of a galvanometer, and a Marianini *re-electrometer*, for this purpose. The same number contains an account of observations at Brussels, on the Periseides, in 1874. M. Louis Henry contributes chemical papers on hyponitric anhydride and on acetylenic hydrocarbons. M. Plateau expounds an arithmetical "recreation," and M. Dubois makes morphological remarks on species of *Xanthoura.—English Mechanic.*

Immense Photographs.—There are now on exhibition in Paris, says the *Revue Industrielle*, the two largest photographs which have been made since the introduction of the art. One of these photographs represents the principal facade of the New Opera, the other one of the bronzes—the Departure, by Rude—of the Arc de Triomphe de l'Etoile. Each of these prints measures 4 ft. 3 in. in length and 3 ft. 4 in. in height. They were obtained in one single piece, by well-known processes, and with the aid of a large and specially constructed camera. Except in some of the effects of perspective, which perhaps are not reproduced with absolute fidelity, especially the portion representing the dome of the Grand Opera, which appears, on the photographs, to crown the facade instead of being in a plane further back, all the lines of the pictures are of remarkable excellence; the mouldings, the busts, the medallions, the inscriptions, and even the minutest details being reproduced with rare perfection. The attempt is being made to secure pictures even larger than this.—*English Mechanic.*

ON THE FRICTION OF AIR IN MINES.*

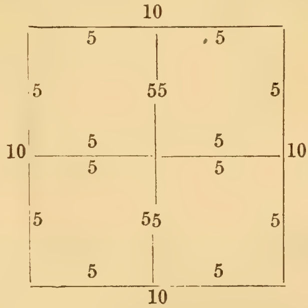
BY J. J. ATKINSON.

(The amount of friction is reckoned as estimated by the amount of the pressure or force required to overcome it.)

NUMEROUS experiments have been made to find out the laws that govern the friction of air and gases, both in pipes having a uniform section, and, to a less extent, in the irregular air-ways of mines. By these experiments, the following laws have been found to hold good in practice:

The pressure required to overcome the friction of air increases and decreases in exactly the same proportion that the area or extent of the rubbing surface exposed to the air increases or decreases; so that when the velocity of the air, and the sectional area of the air-way, remain the same, the pressure required to overcome the friction is proportional to the area or extent of the rubbing surface exposed to it; and hence, if we double or treble the extent of the rubbing surface, we also double or treble the friction, or, what is the same, the force or pressure required to overcome it. The rubbing surface, of course, depends upon the circumference or perimeter of the air-way, and upon its length. The rubbing surface is found by multiplying the perimeter by the length of the air-way, where it has a uniform section. A circular pipe or air-way offers less rubbing surface, for the same length, than any other form or shape of air-way of equal sectional area; because the circumference of a circle is less, in proportion to its area, than the perimeter or any other figure is to its area. A circle whose area is 1 has a circumference of 3.545, or rather more than $3\frac{1}{2}$; the perimeter of a square is 4, when its area is 1; so that about 7 yards of square pipe would offer the same resistance as 8 yards of round pipe, having an equal size or area of section, when the same quantity of air passes through them in a given time.

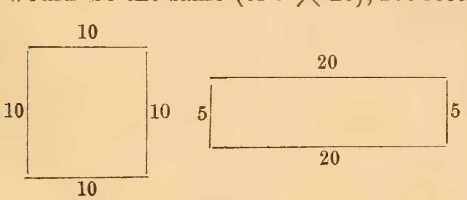
It is true that the friction of air or gas, in passing through the same pipe or air-way, varies in just the same degree that the density of the air or gas may vary; but in air-ways in coal mines the air has always nearly one and the same density, and it is only in particular calculations that it becomes requisite to notice its changes of density, in reference at least to this part of the general subject, since they are so small in amount. This is the case as regards friction, but the effects of variations in the density of the air circulating in mines are more sensible in producing pressure, operating either in favor of or against the ventilating pressure, in rise or dip workings; but these effects belong more especially to another part of the subject. In an air-way 5 feet square, the perimeter of a section is $4 \times 5 = 20$ feet; and if it is 1,000 long, the rubbing surface is $20 \times 1{,}000 = 20{,}000$ square feet. In an air-way 10 feet square, the perimeter of the section is $4 \times 10 = 40$ feet; and if it was 1,000 long, the rubbing surface would be $40 \times 1{,}000 = 40{,}000$ feet; so that, on comparing the two cases, it will be apparent that for four times the area there is only two times the extent of rubbing surface. If such an air-way as that last mentioned (10 feet square, and having a rubbing surface of 40,000 square feet for every 1,000 feet in length) were divided into four equal-sized square air-ways, the rubbing surface exposed to the moving air would be



exactly double by the division; and there would be 20 feet of perimeter for each of the four air-ways, or 80 feet on the whole; so that for a length of 1,000 feet the rubbing surface for the four small air-ways would be 80,000 square feet, or exactly twice as great as that for the one large air-way, although the united areas of the smaller air-ways would be exactly equal

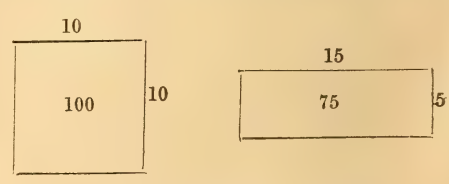
* An Essay read before the Manchester Geological Society, by J. J. Atkinson, Government Inspector of Mines.

to that of the single large one. In one case there would be a single air-way 100 feet in area, and in the other four smaller air-ways, each 25 feet area; but the rubbing surface, and therefore the friction and the pressure required to overcome it for the same gross quantity of air, would be twice as great in the four small as in the one large air-way having the same area. And from this fact we learn that one large air-way is preferable to a number of smaller ones, even if they together make up the same sectional area or size. In practice it often happens, however, that a number of small air-ways can be made and maintained at less cost than one large air-way presenting an equal sectional area; and, in such cases, a few extra air-ways of small area may more than compensate in utility and make up in cost for the absence of one extra-sized air-way; and hence the futility of insisting upon the sectional area of air-ways in mines being of any particular amount, without specifying their number, beyond requiring that one at least in each split be large enough to admit of persons travelling in it. The same principle may be illustrated by taking two air-ways of equal size or sectional area, but having different forms or shapes of section; supposing one of them to be 10 feet high and 10 feet wide, its size or area of section would be 10 × 10 = 100 feet; and supposing the other air-way to be 20 feet wide, but only 5 feet high, the area would be the same (or 5 × 20), 100 feet.



The air-way 10 feet square would have a perimeter of section 4 × 10 =40 feet, while the other would have a perimeter of (20 + 20 + 5 + 5) 50 feet, compared with only 40 in the former; so that for equal lengths the friction of the air would only be 40 in the square air-way compared with 50 in the oblong one; and the friction in 50 yards of length in the square-shaped air-way would be no more than that in 40 yards of length in the oblong one for the same quantity of air. Since the air in a mine presses with nearly the same force upon every square foot, it is quite natural that the frictional resistance should be greater or less in amount, to the same extent that the rubbing surface or number of square feet exposed to the air is greater or less; and this is the general law or principle that has just been stated and illustrated by examples.

The pressures employed to ventilate mines are commonly reckoned at so much per square foot of area, and not by the entire pressure employed, which is equal to the number of square feet multiplied by the pressure on each square foot of sectional area in the shaft or air-way. For instance, a ventilating pressure of 10 lbs. to the square foot on an air-way 100 feet in area is equal, on the whole, to 10 × 100 = 1,000 lbs. If the same pressure of 10 lbs. per foot is applied to an air-way of only 50 feet area, the total pressure is only 10 × 50 = 500 lbs.; owing to the area being one-half, the total or gross pressure is also only one-half. In order to get the same total pressure, we must make the pressure per foot greater in the same proportion that the area is less, when the rubbing surface and *velocity* of the air are to be the same in two cases. If we reckoned ventilating pressure by its total amount, we would not require to notice this law, it is so self-evident; and it is only because we speak and treat of it as so much pressure per *square foot* that we require to consider the number of square feet to which it is applied. If there were two air-ways, one just twice the area of the other, the *velocity of the air* and *the extent of rubbing surface* being the same in each, then we must apply twice the pressure to each square foot of the small one that is required by the larger one, to overcome the equal amount of friction in the two air-ways, the quantity of air passing in the smaller one being just one-half of that in the larger. As an example, if we had an



air-way 10 feet by 10 feet the area would be 100 feet, and the perimeter of section

40 feet; and another air-way 5 feet high by 15 feet wide, the area would be 75 square feet, or just 3-4ths of the area of the former; the perimeter of section would be, however, exactly 40 feet in both air-ways. In the larger air-way we would only require to employ 3-4ths of the pressure on each foot of surface (that is to say, 3-4ths of the water gauge) that we would require to employ on each foot of the smaller area, so as to make up the same total ventilating pressure—the rubbing surface for an equal length of air-way being the same in the two cases, because the perimeter of their sections are equal, and the velocity of the air being taken as the same in the two cases, the quantities of air per minute would be simply proportional to their respective areas under these circumstances.

This second law relating to the friction of air in mines need not have been noticed at all if we had reckoned ventilating pressure as a whole; but as we generally speak of it as so many pounds per foot, we must also take into account, as has previously been remarked, the number of square feet to which it is applied—that is, the area of the section of the air-way—in the same manner that the area in inches of the cylinder or piston of a steam engine multiplied by the pressure on each square inch gives the total force applied to the piston. An inch of water-column, as shown by a water-gauge, represents a pressure of about 5.2 lbs. per square foot.

The third general law relating to the friction of air in mines is, that the pressure required to overcome the friction in the same air-ways *varies* (that is to say, increases or decreases) in the same proportions that the *square* of the velocity of the air increases or decreases; so that a double velocity of air, in the same air-way, meets with a *double double*, or four-fold resistance; a treble velocity meets with a *treble treble*, or nine-fold resistance; and a velocity of four times as great gives rise to a resistance four times four, or sixteen times as great. In the same way a half velocity meets with one-half of a half, or 1-4th of the resistance; 1-3d of the velocity encounters only a third part of a third, or 1-9th of the friction, and so on.

The third law of friction, at first sight, looks rather complex. Consideration, however, shows it to be quite natural, because, if we double the velocity of the air in the same air-way, we, in the first place, cause twice the quantity of air to meet the resistance in a given time; and, in addition to this, every part of this double quantity meets every resistance with a double velocity or momentum; the double quantity of air, and the double velocity taken together, may well be supposed to give rise to a *double double*, or four-fold resistance; and this is the true law. Again, if we treble the velocity of the air, we thereby cause three times the number of particles to meet the resistance in each moment of time, and this alone should treble the resistances; but, in addition to this, the treble quantity meets the resistances with three times the speed or momentum, which *trebles the threefold* resistance that arises from the threefold number of particles of air that meet the resistances each moment of time; on the whole making a ninefold resistance for a threefold quantity of air in a given time.

The laws of ventilation would be very simple, quite as simple, indeed, as they are natural, were it not that, in lieu of the mere quantity of air circulating in a given time, or the mere velocity of the air, we must make use of the square of the quantity, or, what is the same, the square of the velocity, in our calculations; and, as a matter of course, in calculations for comparative results, if we employ the squares of the quantities or velocities, we must expect, as results, not the quantities or the velocities simply, but their squares, and therefore it will be necessary to extract the square roots of the results so obtained in order to get at the simple quantities themselves.

It has already been stated that there is one other principle bearing on the friction of air passing through mines, to the effect that it is greater or less in the same proportion that the density or weight of each cubic foot of air is greater or less; so that if each cubic foot of air had a double weight it would have a double amount of friction; or, if it had only half the weight, it would have only half the amount of friction in the same air-way, when the velocity or the number of cubic feet per minute is the same; but the variations in the density of the air in mines are so very small, compared with the whole density, that the effects of this law on the amount of ventilation are very small—so small, indeed, as to be practically unfelt, at any rate as an increase or reduction of friction in the moving air; even in an upright or vertical shaft the density of the air would only be altered, on the average, by about 1-60th part of its amount, compared with a level air-way, supposing the shaft to be 150 fathoms deep, so far as the pressure of the atmosphere is concerned. The changes of density arising from the heat of upcast shafts, in expanding the air, have a greater effect, so far as such shafts alone are concerned, under furnace ventilation; but this does not affect the friction of the air in the workings of the mine; and, even in these shafts, the lessened density, arising from expansion by heat, has its effects on reducing the shaft friction greatly modified, by the greater velocity due to the increase in the volume of the air; this increased velocity does more than make up, by the accompanying increase of friction, for any reduction in such friction that is due to the lessened density of the air in every case; the friction, in fact, increases or decreases in just the same proportion that the volume of a given weight of air increases or decreases, whether the change of density arises from change of temperature or from change of pressure. Supposing the temperature of the air in a mine to be 60° in winter and 65° in summer, on the average, such a change would only alter the friction in such mine by about 1-104th of its amount. In summer the friction would be 1-104th greater than in winter for the same weight of air, but it would, at the same time, be about 1-104th part less for the same volume of air—an alteration hardly worth notice for the present purpose. The total friction or the total pressure due to the friction of air rubbing against the top, bottom, and sides of the air-ways of mines is not very well ascertained; and all the experiments, at least all that have come under my notice as having been made for the purpose, have been in some respects of a rude character, the necessary particulars not being given in the accounts published to fix with rigid accuracy its amount.

From the best accounts of such trials, it seems probable that for every foot of rubbing surface, and for a velocity in the air of 1,000 feet per minute, the friction is equal to 0.26881 feet of air column of the same density as the flowing air, which is equal to a pressure, with air at 32°, of 0.0217 lbs. per square foot of area of section; calling this the *co-efficient of friction*, we have the following rules with respect to the friction of air in mines:

Total pressure................	$pa = ksv^2$	(1)
Rubbing surface..............	$s = \dfrac{pa}{kv^2}$	(2)
Velocity squared..............	$v^2 = \dfrac{pa}{ks}$	(3)
Co-efficient of friction..........	$k = \dfrac{pa}{sv^2}$	(4)
Pressure per foot..............	$p = \dfrac{ksv^2}{a}$	(5)
Area of section................	$a = \dfrac{ksv^2}{p}$	(6)

Where p = pressure per sq. foot,
a = sq. feet of sectional area.
s = the area of rubbing surface exposed to the air.
v = the velocity of the air in thousands of feet per minute—1,000 feet per minute being taken as the unit of velocity.
k = the co-efficient of friction in the same terms or unit as p is taken in.

Putting these formulæ into words, we have the following set of rules:

(1.) *To find the total pressure* due to friction.*—Multiply the co-efficient of friction by the extent of the rubbing surface, and the product by the square of the velocity in thousands of feet per minute; that is to say, by the square of the quotient resulting from dividing the velocity in feet per minute by 1,000.

(2.) *To find the rubbing surface.*—Di-

* The *total pressure*, in these rules, is found by multiplying the sectional area of the air-way, in feet, by the pressure per square foot.

vide the total pressure by the product of the co-efficient of friction and the square of the velocity in thousands of feet per minute.

(3.) *To find the velocity.*—Divide the total pressure by the product of the co-efficient of friction and the rubbing surface; this gives the square of the velocity, the square root of which is the velocity itself, in thousands of feet per minute; this multiplied by 1,000 will give the velocity in feet per minute.

(4.) *To find the co-efficient of friction from experiments.* — Divide the total pressure by the rubbing surface and the square of the velocity (in thousands of feet per minute) multiplied together.

(5.) *To find the pressure on each foot of section.*—Multiply the co-efficient of friction, the rubbing surface, and the square of the velocity (in thousands of feet per minute) all into each other, and divide the product by the area of the section.

(6.) *To find the area of the section.*—Multiply the co-efficient of friction, the rubbing surface, and the square of the velocity (in thousands of feet per minute) all into each other, and divide by the pressure on each foot of sectional area.*

The foregoing rules embrace only the pressure due to friction, and not that due to the creation of velocity, so that they may be regarded as being true of long pipes and air-ways, as they are given, but as requiring an allowance for the pressure due to the velocity in short pipes and air-ways. This allowance renders the rules much less simple.

Now, these rules, which are found out by practical trials or experiments, lead us to many very important conclusions in reference to the best mode of conducting the ventilation of mines, in proof of which it would be easy to multiply examples.

These laws of friction may be illustrated by the following example:

In an air-way 10 feet square = 100 feet area, and 25,000 feet, or nearly five miles long, if the velocity of the air were 1 foot per second, or 60 feet per minute, the quantity of air would be 6,000 feet per minute—the pressure due to friction (taking the pressure at 14.7 lbs. per square inch, and the temperature at 32°) would be .7812 lbs. per square foot of sectional area of the air-way, the horse-power being .142.

In another air-way of equal length, but instead of being 10 feet square only five feet square, giving only 25 feet or 1-4th of the area of the larger air-way, we have the following results: The rubbing surface in the small air-way would only be one-half of that in the large one; but, on the other hand, the area to which the ventilating pressure would apply would only be 1-4th; and at the same time the velocity of an equal volume of air would be increased fourfold in the lesser air-way; this increase of velocity alone making sixteen times the friction, so that on the whole it would be thirty-two times as great; making the pressure on each square foot 24.998 lbs., being thirty-two times as great as in the large air-way. And therefore, on the whole, the *power* expended would be also thirty-two times as great in the small as in the large air-way, for the same amount of ventilation per minute: the coals consumed would also be thirty-two times as great. If furnace ventilation were used, and the heat of the upcast shaft and pressure per foot were the same, instead of 6,000 cubic feet per minute, as in the large air-way, we should only have 1,061 feet in the smaller one; but, in this case, the coals burnt would only be $\frac{1}{\sqrt{32}}$, or between 1-5th and 1-6th of the former quantity, and the power would be less in the same proportion, for the lesser quantity of air. This shows in a striking manner the great advantage of large air-ways.

The calculations relative to the two cases, compared with each other for the example just given, stand thus:

FOR THE LARGE AIR-WAY.

The length is 25,000 feet, and the perimeter of section is $4 \times 10 = 40$ feet; so that the rubbing surface

$$s = 40 \times 25{,}000 = 1{,}000{,}000 \text{ sq. ft.}$$

the area $a = 10 \times 10 = 100$ square feet,

the velocity $v = \frac{60}{1{,}000} = .06$, in thousands of feet per min.;

* If it is preferred to employ in these rules the velocity in feet per minute, in lieu of in *thousands* of feet per minute, the co-efficient of friction, in lieu of .26881, would become .00000026881; and if the velocity is taken in feet per second, it would become .000967716.

and $k = .26881$, being the co-efficient of resistance in feet of air-column of the same density as the flowing air.

Now by formula (5) we have

$$p = \frac{k\,s\,v^2}{a};$$

giving in this case

$$p = \frac{.26881 \times 1{,}000{,}000 \times (.06 \times .06)}{100}$$

$= 9.67716$

feet of air-column as the pressure required.

Taking the flowing air to have had the density due to a temperature of 32°, and to a pressure of 14.7 lbs. per square inch, a cubic foot of it would weigh .080728 lbs., and, therefore, such a column would represent a pressure of

$9.67716 \times .080728 = .7812$ lbs. per sq. ft.;

and hence the horse-power due to the friction of 6,000 cubic feet of air per minute, in passing through such an air-way, would be

$\frac{6{,}000 \times .7812}{33{,}000} = .142$, or about 1-7th of a horse-power.

FOR THE SMALL AIR-WAY.

Proceeding as in the former case, we have

$$\frac{.26881 \times (20 \times 25{,}000) \times (.24 \times .24)}{25}$$

$= 309.66912$

feet of air-column as the pressure required for putting the same quantity of air, 6,000 cubic feet per minute, into circulation; being equal to a pressure of

$309.66912 \times .080728 = 24.9989$ lbs. per square ft.; giving

$\frac{6{,}000 \times 24.9989}{33{,}000} = 4.545$ horse-power.

If the *pressure per square foot* was the same in the small as in the large air-way, or .7812 lbs. per square foot, the air-column would be $\frac{.7812}{.080728} = 9.67716$ feet high; and the square of the velocity (in thousands of feet per minute) would by formula (3) be

$$v^2 = \frac{9.67716 \times 25}{.26881 \times (20 \times 25{,}000)} = .0018$$

and hence the simple velocity, in thousands of feet per minute, would be

$$v = \sqrt{.0018} = .042426,$$

and the velocity in feet per minute would therefore be

$$.042426 \times 1{,}000 = 42.426;$$

and this gives for the quantity of air that would be put into circulation in the small air-way, by the same pressure per foot that is required to circulate 6,000 cubic feet per minute in the large one,

$42.426 \times 25 = 1{,}061$ cubic feet per minute, as has been stated.

To circulate 1,061 cubic feet of air per minute in the small air-way would, however, only involve the application of

$$\frac{1{,}061 \times .7812}{33{,}000} = .0251 \text{ horse-power},$$

which, under the conditions of the small air-way, and the assumed pressure, represents the entire power due to the friction of the quantity of air that would circulate in it.

Air, in being heated under a constant pressure, expands 1-459th part of its volume at the temperature of zero of Fahrenheit's thermometer for each degree of temperature imparted to it; 459 cubic feet of air at 0° become 469 at 10°, 479 at 20°, 489 at 30°, and so on. 1,000 cubic feet of air at 32°, the temperature of melting ice, expand to 1,366½ cubic feet, at 212°, the temperature of boiling water. To find the relative volumes occupied by equal weights of air, under equal pressures, but at different temperatures, we have simply to add the constant number 459 to the temperatures, and the sums give the relative volumes. The ordinary pressure of the atmosphere is equal to that of a column of water about 34 feet or 400 inches in height; we, however, seldom employ a difference of more than 2 or 3 inches of water column as ventilating pressure in mines. The pressure of the air is about 2,116 lbs. per square foot, but we seldom employ more than 10 to 17 lbs. extra as ventilating pressure. Owing to the ventilating pressures being so small, the changes of density in the air of mines (as it circulates), arising from changes of temperature, the mixture of watery vapor or steam, the gases given off, and one or two other causes, give rise to small local pressures in the various splits of air in a mine. In rise splits these local pressures usually operate against the general ventilating pressure, and lessen the quantity of air that would otherwise circulate. In dip splits these small local pressures commonly act in the same direction as the general ventilating pressures, and so add to the amount of their ventilation. This arises from the return air of any split being generally less dense than the intake air.

The laws of ventilation lead us to conclude that if we increase or decrease the total ventilating pressure, and total quantity of air circulating in a given time, where the seam of coal is perfectly level, each way or split will get a *fixed share* of the whole of the air entering the mine, no matter how long or short may be the different splits, and no matter how great or small may be the quantity of air. This is contrary to an old notion, that a short split gets an increasing and a long one a decreasing share of any lessened amount of ventilation, apart from considerations as to the rise or dip of the seam. Not long ago this point was severely tested, by numerous experiments, at several collieries; the results showed that the old idea was a mistaken one, and that the only changes that took place in the *proportion or share* of air going to different splits, with a reduced ventilation, arose from their relative rise or dip, together with the relative densities of the intakes and returns, and had no connection with the mere lengths of the splits. In ordinary cases, where the air of the returns is less dense than that of the intakes, if we have a short level split regulated so that, with the full ventilating pressure, it gets the same amount of air as a long dip split, and if we then halve the total quantity of air circulating, we find that the short level split no longer gets its share, but only a quantity less than that which goes into the long dip split; the very reverse of this is the case where the long split is a rise one; and these results are perfectly agreeable to the laws of ventilation that have been stated. In practice, and with the ordinary splits of air used in mines, except in extreme conditions as to the amount of rise and dip, and changes of density in the air, and in the amount of ventilation, the *share or proportion* of air going into the different splits of a mine is nearly maintained, whether we increase or lessen the total amount of ventilation; and any deviation from this depends upon the rise or dip of the splits, and not at all upon their relative lengths. In practice, then, when any reduction of ventilation has been brought about, we should generally find that the rise splits have been more affected than dip ones, if even the rise splits are shorter than the dip ones, and we should therefore expect to find accumulation of gas in the short rise splits rather than in the long dip splits of the mine. The greater the rise the greater is the danger of this, quite apart from the mere length of the splits, supposing them to be equally well ventilated to begin with.

So far as experiments have gone, they show that if we had a series of equal sized and similarly shaped air-ways, made of different substances, the friction of air in passing through them would differ according to the nature of the substances.

Taking the friction in earthenware pipes at	100
In the air-ways of mines it would also be.	100
In sheet-iron pipes, new and clean	39
In " " rusty inside	10
In cast-iron pipes, sooty inside	20
In " " tarred inside	18
In tin pipes the friction would only be	10

So that 1-10th of the pressure would send the same quantity of air through a tin pipe that would be required to force that quantity of air through an earthenware pipe of the same size in the same time.*

From these laws we learn, that the quantity of air that will pass through any mine is greater or less as the ventilating pressure is greater or less, but not in the same proportion. When the air-ways are the same, the quantity of air only alters in the proportion of the square root of the pressure; so that a fourfold pressure only gives a double quantity of air, and a ninefold pressure only gives a treble quantity of air. But, on the other hand, one-fourth of the pressure still gives one-half of the air, and one-ninth of the pressure gives one-third of the air. The changes in the quantity of air, then, are

* See table, following page.

Table showing the values of the co-efficient of friction, represented by the letter k, in the formulæ given at page 212, being the height in feet of air column of the same density as the flowing air, required to overcome the frictional resistance encountered by 1,000 cubic feet of air per minute in passing through a passage having one foot of sectional area, and presenting one square foot of rubbing surface to the air in motion.

Nature of the material composing the pipe or air-way.	State of the internal or rubbing surface exposed to the wind.	Observer's names.	General temperature of the air or gas.	Head of column of the same density as the moving air or gas required to overcome the friction; being the co-efficient of friction $= k$.	Remarks.
Burnt earth	Clean	Peclet	Hot	0.26881	In applying these values of k to the formulæ at page 212 since they are calculated for velocities of which the unit is 1,000 feet per minute, the real velocities in feet per minute must be divided by 1,000, to give the value of v in the formulæ; and v in the formulæ must be multiplied by 1,000 to give the velocity in feet per minute.
Galleries of a coal-mine	Ordinary state	G. C. Greenwell	Cool	0.25436	
Sheet-iron	New and clean	Peclet	Hot	From 0.10583 to 0.06773	
Cast-iron ?	Ordinary ?	Mons. Rudler	Hot	0.08466	
Cast-iron	Sooty	Peclet	Hot	0.05292	
Cast-iron	Old, tarred	Girard	Cool	0.04844	
Gas in pipes (cast-iron)	Ordinary	Mr. Hawkesley	Cool	0.03014	
Water in pipes (cast-iron)	Ordinary	Eytelwein	Cool	0.03028	
Sheet-iron	Old and rusty	Girard	Cool	0.02752	
Tinned iron	?	D'Aubuisson	Cool	0.02540	

sluggish as compared with the changes in the ventilating *pressure*, only varying as its square root. The quantity of air, however, is more sluggish still in reference to the *power* employed to cause it to circulate. The quantity of air only varies as the cube root of the power, and of the quantity of coals burnt to produce it; so that eight times the coals only double, and twenty-seven times the coals only treble the quantity of air circulating in a mine, whether the ventilation is produced by furnace action, ventilating machines, or otherwise, so long as the air-ways remain in the same unaltered state. From this we learn, that we must not expect any great general improvement in the ventilation of mines from a mere increase of power; any increase in the quantity of air in the same air-ways is slow, small, and costly, compared with the necessary increase of power required to produce it.

In the same manner these general laws show us, that the quantity of air increases as we decrease or lessen the extent of the frictional rubbing surface; but again, not in the same proportion, but only as the square root of the extent of the rubbing surface. If we could do away with three parts out of four of the rubbing surface, so as to reduce it to 1-4th, other things being the same, we should only double the quantity of air in the mine; if the rubbing surface were reduced to even 1-9th, the quantity of air circulating per minute would only be increased to three times its previous amount. On the other hand, if the extent of workings and rubbing surface were increased to four times, or nine times their previous amount, while the area of the air-ways and the ventilating pressure remained unaltered, the air would only be lessened to one-half or one-third of its previous amounts respectively by such extensions, if we suppose the size of the air-ways and the number of splits of air to remain the same, as well as the ventilating pressure, in each case.

From these laws, then, we learn, that either to increase the ventilating pressure, or to lessen the extent of rubbing surface exposed to the air circulating in mines, is a very slow and very costly mode of proceeding to increase the amount of ventilation, as the quantity of air circulating in a given time alters so slowly with any alteration that may be made in the ventilating power or pressure, or in the mere extent of rubbing surfaces that may be presented to it. For general improvements we must, therefore, look chiefly in some other direction, owing to these being slow and costly modes of increasing the ventilation of a mine.

The same general laws of resistance show us that if we could reduce the velocity of the air, consistently with increasing the quantity circulating in a minute, we should greatly lessen the friction in comparison with the quantity of air circulating, and so obtain an increased quantity for the same amount of friction, or by the same ventilating pressure. This object is accomplished by splitting the air, so that instead of allowing the whole of the air to traverse the whole of the workings, a separate portion is taken into each different district of workings, and also brought out in a separate channel to a point near the up-cast shaft, after it has done its work. The air, as a whole, thus has as many ways to go in, and as many to come out by, as there are separate splits in the mine; the extent of the rubbing surface is not lessened by this, on the whole, but the area offered to the air is greatly multiplied; and although the velocity of each current may be reduced, still, on the whole, the quantity of air in all the splits is very much greater than if there were only one single current in the mine, even when the ventilating pressure is the same. Splitting the air does not necessarily enlarge the area offered to the air in the shafts, and the increased resistance arising from the increased quantity and velocity of air in them sets a limit to the benefits resulting from splitting the air in a mine. Owing to the resistance offered by the shafts, we dare not have more than a limited number of splits in a mine, because although every split adds to the total quantity of air circulating, still in each separate split the quantity ultimately becomes less and less, and if the number be too great, the current of each becomes too feeble and slow to sweep into the holes, corners, and places driven in advance of the actual current; and besides this, powder smoke is a long time in being carried away from the workmen. Still it is a fact that an additional quantity of air, on the whole, is obtained from every new split that is made.

The following general rules should be observed in splitting the air in mines:

Every principal split of air should commence as near as possible to the bottom of the downcast shaft, and should have a distinct air-way to return in, as nearly as may be, to the furnace or the bottom of the upcast shaft, except in cases where it is necessary to mix different currents, lest some one or more of them may be dangerously charged with gas. Splits of air only commencing far into the workings of a mine have comparatively little effect in increasing the quantity of air.

Where the air-ways are nearly of the same area in all parts of a mine, and the gases given off and the workmen employed are pretty evenly distributed, the length of the runs of the different splits should be as nearly equal to each other as circumstances may permit. The observance of this rule has a tendency to render regulators and other obstructions comparatively needless, and so to increase the amount of ventilation.

If we have a number of splits of air in a mine, each with an equal amount of air, then it is necessary so to obstruct each of the shorter splits as to cause their frictional resistances, when they have their proper share of air, to be as great as that of the longest split, when it also has its due share; otherwise they would get too much air, and the longer ones too little. These obstructions, of course, lessen the total quantity of air circulating.

The increased quantity of air obtained by splitting depends greatly upon the relative depths and areas of the shafts, as compared with the lengths and areas of the air-ways forming the workings of the mine. Supposing a mine to have such shafts and air-ways that when there are five equal splits of air the shaft resistances amount to one-half of the resistances offered by the mine—and this is no uncommon case—then, if before splitting the air at all we had a ventilation of 10,000 cubic feet of air per minute, the following are the quantities of air that would circulate by increasing the number of equal splits, while the entire extent of the workings, and the upcast shaft, and the ventilating pressure all remained the same:

No. of Currents.	Quantities of Air on the whole.	Quantities in each split.
1	10.000	10,000
2	27,892	13,946
3	49,449	16,480
4	71.527	17,882
5	90,789	18,158
6	107,800	17,966
10	141,710	14,171

In this case the coals burnt, whether in a furnace or by an engine driving a ventilating machine, would increase in the same proportion that the quantity of air increased, because the power would increase in that ratio. If the coals burnt, and the power remained unaltered, the results would only be as follows:

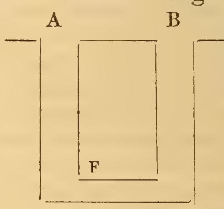
No. of Currents.	Total Quantities of Air per minute.	Quantities of Air per minute in each split.
1	10,000	10,000
2	19,813	9,906
3	29,022	9,674
4	37,121	9,280
5	43,736	8,747
6	48,797	8,133
10	58,556	5,856

Enlarging the sectional area or size of air-ways has a great effect in increasing the ventilation, but it is attended with great cost, and in general terms may be said to be much less effectual than judiciously splitting the air into a series of different currents. The beneficial effects of splitting air are, I believe, more fully appreciated, and the practice is more extensively followed in the Newcastle coal-field than in any other mining district; but even there it too often happens that the splits are made too far from the bottom of the downcast shaft, and are again brought into the same return too soon after they leave the face of the workings. This often arises from pillars being worked away near the shafts, without proper places being left to make additional air-ways leading to and from the more distant parts of the mine. This a very common oversight, and often entails either danger or a serious outlay, which might be avoided by care and forethought.

ON THE MEANS OF APPLYING POWER OR PRESSURE TO PRODUCE VENTILATION.

We have seen that *pressure* is required to put air into motion, and more particularly, to overcome the friction it meets with in rubbing against the top, bottom, and sides of the galleries in mines. We have next to consider the means employed to give rise to this ventilating pressure. There is constantly a pressure of nearly a ton to the square foot in every direction in the air near the surface of the earth, owing to the weight of the air above it; and we must either increase or lessen the amount of this pressure, in order to put the air into motion; and it is only the amount of this increase or decrease, and not the entire pressure, that puts the air into motion and overcomes the friction in mines.

Take the case of two pits or shafts, of equal depth, and having their tops and bottoms on the same level, and filled with stagnant air, which likewise occupies an opening, extending from the bottom of one shaft to the bottom of the other; and suppose that in the first place the weight of the air in one shaft is the same as that in the other, the temperature and other conditions being the same in each, and that the shafts are of the same sectional area or size: in this state the two columns of air exactly counterbalance and support each other, so that there is no motion in the air, and therefore no ventilation is produced; nay, further, if one shaft be ever so much larger than the



other, the air it contains can only press upon that in the smaller one over the area of the smaller section; the air contained in the extra size of the larger shaft resting or pressing upon the sides of the shaft or air-way at the place where the area is lessened, and not upon the air in the smaller shaft; so that whatever may be the relative sizes of the shafts, the air in the one will balance that in the other if the density of the air is the same in each; this may be termed the pneumatic paradox. If, however, by means of a furnace, at F in the diagram, the air in one shaft is heated and expanded, it becomes lighter, bulk for bulk, than the cool air in the other, and no longer balances it; the pressure of the heavier air then overcomes that of the lighter air, and pushes it up the shaft before it, while the cool air from the cool shaft takes its place, but not in a cool state, as it gets heated in its turn in passing over the furnace, so that there is a continual current of cool air going down one shaft which pushes before it a constant current of hot air up the other shaft.

In mines, the air, instead of being allowed to go direct from the bottom of one shaft to the furnace and up the other, is guided by means of stoppings and doors into and along the various passages forming the workings of the mine, before it is brought upon the furnace or into the upcast shaft, and, by this means, a continual stream of air is made to sweep through the workings and mix with and carry off the gases as they are given off, and this is called the ventilation of the mine.

In some cases, men, boys, and horses require to travel in directions that the air is not wanted to go, and in such cases we cannot build up the way by stopping, but have to place doors to stop the passage of the air; in many cases, the opening of a door to allow a person or horse to pass would have a bad effect by allowing the air to pass through it even for so short a time, and to avoid this evil two doors are employed, so that one may be always closed when the other is open. The use of doors in the principal roads of mines is objectionable where it can be avoided, and is much less common, at least in some districts, than formerly; in other districts of the kingdom the number of ventilating doors is very great, notwithstanding the danger and cost attending their use. The neglect of keeping doors shut has, no doubt, often led to serious explosions of gas in mines. In some cases it is necessary that the route of one split or current of air should intersect and cross that of another, and in such cases one current is carried over or under the other by means of drifts or masonry to prevent their coming into contact with each other; this arrangement is called an air-crossing or bridge. When an explosion occurs, the force of the concussion often destroys air-crossings, and thereby interrupts the ventilation; so that they should be avoided as far as possible, and made very strong where they are used in fiery mines.

It has already been stated that where there are several splits of air in a mine, of different lengths, and offering different resistances, we sometimes find that too little air goes into the longer splits, compared with the quantity going into the shorter ones; and in order to correct this evil, we put regulators or contractors into the shorter ones so as to increase the natural resistance they offer, and cause more air to go into the long splits. Regulators, although useful where they are unavoidable, are not desirable, as they contract the air-ways, and so lessen the total quantity of air circulating in the mine in a given time. As far as may be, the routes of the air should be so proportioned that each split may obtain its proper share of air without using any artificial regulators. Doors, air-crossings, and regulators should be avoided in all cases where the circumstances of the mine admit of it.

In order to find the amount of ventilating pressure, and the power arising from the use of a ventilating furnace, we require to know the weight of a cubic foot of air at different temperatures and under different pressures. Careful experiments show that 459 cubic feet of air at 0°, or zero of Fahrenheit, the common thermometer, weigh 39.76 lbs., when the pressure is 30 inches of mercury of the density due to 32°; a pressure equal to nearly 14¾ lbs. per square inch, which is the ordinary pressure of the atmosphere —but it only weighs 1-30th of this, or 1.3253 lbs., when the pressure is only one inch of mercury; and since 459 feet of air at 0° expand exactly a cubic foot for each degree of heat added, we get the following *rule* to find the weight of a cubic foot of air, at any temperature, and under any pressure:

$$W = \frac{1.3253 \times I}{459 + t};$$

where I = the height in inches indicated by the barometer, and t = the temperature by Fahrenheit's thermometer. At 38°, under a pressure of 30 inches of mercury, 100 cubic feet of air weigh just 8 lbs.; a box 5 feet every way would just contain 10 lbs. of such air.

On one occasion, at Hetton Colliery, when 225,176 cubic feet of air per minute were circulating, the average temperature of the air in the downcast shaft was 43½°, and that of the air in the upcast shaft was 211°. Now, by the rule given (if we take the barometer half-way down the shaft to have shown a pressure of 30½ inches of mercury), the weight of a cubic foot of air, taking the average, in the downcast shaft, would be .08044 lbs.; and the pit being 900 feet deep, this air would produce a pressure of .08044 × 900 = 72.396 lbs. on each square foot by its mere weight. The air in the upcast shaft, owing to its being hotter, would be lighter, and only produce a pressure on each foot = 54.297 lbs.; and hence the difference of pressure on each square foot of area, between the two columns of air, would be = 18.099 lbs. Now in order to find the horse-power producing ventilation, we require to multiply this difference of pressure of 18.099 lbs. on the square foot, by the number of cubic feet of air circulating per minute, and then to divide the result by 33,000, the number of lbs. raised one foot high per minute by a horse-power. In this case then, we find the ventilating power at Hetton Colliery must have been

$$\frac{\overset{\text{lbs.}}{18.099} \times \overset{\text{c. ft. pr. min.}}{225{,}176}}{33{,}000} = 123\tfrac{1}{2} \text{ horse-power};$$

225,176 cubic feet of air per minute being in circulation at the time. Some part of the extra heat of the air in the upcast over that in the downcast shaft, would have arisen from the heat of the mine, and would have caused what is called a natural ventilation, even if furnaces had not been used. But natural ventilation is generally very small in amount, and cannot be depended upon, as, in hot weather, the downcast column of air is little or no cooler or denser than the air in the upcast, and, by making the weight or pressure of the two air columns equal, there is a liability to stop all ventilation.

Where furnaces are used to produce ventilation, the deeper the upcast shaft the better; because this gives rise to a longer upright column of hot air, and so causes a greater ventilating pressure, and consequently a brisker ventilation. Furnaces are not well suited for causing ventilation in shallow pits, for this reason; and sometimes machines are fixed at the top of the pit to pump the air through the mine. These machines, for the most part, exhaust air out of the upcast shaft, and the pressure of the denser air in the other, or downcast shaft, causes the current. Such a ventilating machine, like a furnace, acts by rendering the upcast column of air lighter, bulk for bulk, than the air in the downcast shaft; the same effect is sometimes produced by large fans, the machines mostly being worked by steam engines. A few of these ventilating machines are used in the south of England, and in Wales, and a great number are used on the Continent. Ventilating machines of the best construction consume less coals (to produce the same quantity of ventilation) than furnaces, except in very deep and dry shafts. But coals are plentiful at collieries, and the liability of ventilation being suspended by the breakage of the machinery, and the inconveniences attending the stopping of the ventilating machine for repairs to itself or the engine, together with the difficulty of applying ventilating machines to working shafts, render them, in the opinion of many persons, less to be depended upon than furnaces in general. Taking the average of eleven different collieries in the Newcastle district, each pound of coal puts 13,000 feet of air into circulation, by the action of furnaces. In some collieries two or three times as much air is circulated by each pound of coal as in others, depending on the depth of shaft, and its state as to dryness or wetness, and on the friction of the air in the shafts and in the mine itself. There are in Wales some seven or eight ventilating machines at work, producing ventilations varying from 16,000 to 75,000 cubic feet of air per minute. The largest machine is one recently erected at Deep Duffryn Colliery, which, with air-ways of sufficient area, is capable of producing a ventilation of double the latter quantity.

Jets of steam were proposed to produce the circulation of air in mines a few years ago, but by an elaborate series of experiments their effects were found to be far below that of furnaces, and the cost to be very great; the idea of their utility for ventilating mines was therefore abandoned. The useful work contained in a jet of steam probably varies as the cube of the velocity of the steam, so that if the same quantity of water was converted into steam, in a given time, the power contained in it would depend upon the smallness of the jet orifice it had to escape through; by halving the area of the jets we should obtain eight times the power, and should therefore get a double quantity of air through the same mine; by reducing the area of the jets to one-third, we should obtain a treble quantity of air, by the same quantity of steam, in a given time. At least these are the results given by calculations made upon the principles of mechanics, which are found to be true for streams of water and air. I have not taken pains to compare them with the results of the experiments on steam jets as applied to ventilation, because the results seemed to hold out no hope of steam jets ever being made available for ordinary ventilation. There are, no doubt, temporary and peculiar circumstances under which steam jets may be useful in the production of ventilation, such as cases where it is either unsafe or impracticable to use ordinary furnace action.

Falls of water are sometimes employed in downcast shafts to cause a current of air to descend; but as the water has, for the most part, to be raised again from the mine, and as the effects they produce are small, in proportion to the power employed, this mode of ventilation is seldom used, except where furnace action or other means are necessarily excluded.

OF THE INSTRUMENTS USED IN CONNECTION WITH THE VENTILATION OF MINES.

Barometer.—The pressure of the atmosphere in different states of the weather varies from 28½ to 31 inches of mercurial column, being from 2,016 to 2,192 lbs. per square foot; and it is found that the natural discharge of gas in mines becomes greater as this pressure becomes less, so that the reduced atmospheric pressure, as shown by a barometer, is a warning that an increased quantity of gas may be expected to be given off in mines, and, therefore, calls for increased care and vigilance to keep the ventilation at its greatest point, and for taking precautions against the enemy. The air pent up in goaves and abandoned excavations also expands in volume from the reduction of pressure which causes the fall of the barometer; the increased volume being given out into the air-ways, and often being mixed with gases necessitating careful attention, as the barometrical pressure of the atmosphere is lessened; the more suddenly the pressure falls the more observable are these results. A very *sudden* fall of the mercury is accompanied by a worse effect on mines than a greater fall, provided it takes place less rapidly. An increase or decrease of the pressure of the atmosphere has little or no effect in altering the *volume* of air passing through a mine in a given time, although it alters the *density* and *weight* of such air often to a considerable extent.

A good portable barometer may be used to ascertain the friction of air in passing along air-ways, because the loss of pressure, by friction, as the air circulates, is always taken off the pressure of the air itself; so that in level air-ways the air is less and less compressed as we proceed in the direction followed by the air, and the reduction of pressure is an exact measure, in such air-ways, of the pressure spent on friction.

When the air-way rises or dips, allowances for this have to be made in finding the amount of friction from the pressure of air in this manner. Aneroid barometers appear to be better suited for use in mines than the common barometer or weather glass, as they are more portable, less liable to derangements, and almost equally reliable, at least for comparative indications, which are just as useful as absolute ones in mines.

Thermometer.—The thermometer is used to measure the heat of air in mines; when the fresh air, going down a downcast shaft, is heated, it expands and becomes lighter, and is therefore less able to force the air before it through the mine; in other words, by being heated, the weight of the column of air in the downcast shaft is reduced till it is more nearly equal to that in the upcast shaft, and consequently the ventilating pressure is lessened, and therefore the quantity of air circulating is also reduced in amount. By the use of this instrument we find the difference of temperature between the air in the downcast and that in the upcast shaft, and so are able to calculate the ventilating pressure due to the action of a furnace.

Water Gauge.—The water gauge is merely a glass tube, bent into the form of the letter U with a scale of inches and parts, by which we can measure the difference between the height of the water in one tube and that in the other. It has already been stated that the air loses the pressure that is spent on the friction as it progresses along an air-way. Now, when an air-way happens to turn so as to come nearly parallel to itself, there is often a door or stopping separating the two adjacent parts of the same air-way, and this instrument enables us, in a direct way, to measure the amount of pressure that is spent on friction between the two adjoining parts of the air-way so situated. The air has less pressure on the outcome or return side of the separation than the air on the intake side, which has not yet met with the friction of the intervening distance of air-way. If the water in one leg of the tube is exposed to the pressure of the intake air, while that in the other is exposed to the lesser pressure of the return air, the greater pressure on the intake leg of the water gauge sinks or depresses the surface of the water in that leg, and raises it in the other leg; the difference of level, which represents the ventilating pressure spent on the air-ways lying beyond the place where it is taken, is seldom so much as three inches, and often only one inch in well ventilated mines. The amount of water gauge can be increased, either by increasing the ventilating pressure, and consequently also the quantity of air circulating in a given time, while the air-ways are in the same state, or it can be increased by falls of material, or other obstructions in the air-ways, even while they lessen the quantity of air circulating; because such obstructions increase the frictional resistance of the air, and the gauge is a measure of that resistance. A water gauge does not show the shaft resistances when used in a mine; the pressure shown by the water gauge is equal to the general shaft ventilating pressure, *less* or *minus* the friction due to the air in the shafts and in the air-ways extending from the shafts to where the gauge is tried. It is also a measure of the resistances the air meets with in the workings lying beyond it, *less* or *minus* any local force, arising from the air in the returns being lighter than that in the intakes, in dip-ways; or it is equal to such friction added to any such pressure that may operate against ventilation from the same cause in the rise-ways or splits of air in the mine; and in cases where the air of the returns is more dense than that of the intakes, the effects arising from the dip or rise of the workings will, of course, operate in the reverse manner upon the indications of the gauge. When the air-ways remain in the same state, the amount of water gauge increases as the ventilation increases, and falls as it decreases; but the proportion of variation of the gauge-pressure is much greater than that of the quantity of air circulating; the *square* of the quantity of air, except in so far as local pressures may interfere, is proportional to the pressure indicated by the gauge, because the friction varies as the square of the quantity of air.

The *Anemometer* is an instrument used to measure the rate at which the air flies in mines. That invented by the late Mr. Biram is the one mostly used in English mines; it is not a very easy matter to find how much each of these instruments requires to be allowed for its own working friction; no perfect rule has yet been established for this purpose, although one is much needed. An approximate rule requires that a constant quantity should be added to the number of revolutions in a minute, no matter what may be the speed of the wind or of the instrument; and that the sum so obtained should be multiplied by another constant quantity, to give the velocity of the air in any terms in which we wish to find it. Coombes's anemometer can be put into or out of gear by pulling strings attached to it; this instrument is said to give very correct results, and is greatly used on the Continent; it is, however, more troublesome to use than Biram's anemometer, and is seldom seen in our mines. There are a few other kinds of anemometers; but a good and simple instrument, or mode for finding the velocity of air in motion, has probably yet to be contrived.

The Hygrometer.—In fine experiments, the hygrometer is used to ascertain the proportion of moisture in the atmosphere of mines, from whence its density and also its capacity for heat are found. Mason's wet and dry bulb hygrometer is better adapted for use in mines than the more delicate one of Daniel. The return air in nearly all mines is found to be saturated with vapor of water; that is to say, it contains the greatest quantity of vapor that can exist in it at its temperature; and a portion of vapor is condensed by the least degree of cooling that takes place in the air. An atmosphere saturated with vapor is lighter, bulk for bulk, than another at the same pressure and temperature, but containing less vapor.

In the discussion which followed—

Mr. Atkinson said: Supposing you have a long split and a short one in the same mine, and you regulate or contract the short one by an artificial obstruction until the quantity going into each is equal; then supposing, from some cause or other, the general ventilating pressure is gradually reduced: what would be the result? Would the short split get half of the remaining total quantity of air, or would it get less or more? That question would have been answered in my younger days by saying that the short split would ultimately take the whole of the air, and none would go to the long one. Now, however, it is a fact, which I have proved over and over again, that if the air-ways are level, and you reduce the ventilating pressure, each split will take its original *proportion;* but if the long one is a dip-way and the short-way is a level one, on reducing the gross quantity of ventilation the long-way gets more than its original *share* of the reduced quantity, and so takes the lead of the short split. If, on the other hand, the long split is a rise and the short a level, on reducing the gross quantity the long split gets less and the short one gets more than its *share.* Supposing one split gets 60 per cent. and the other 40 per cent. of the total to begin with, if the air-ways are level, each will get the same percentage when the gross amount is lessened. Just the reverse results take place if you take the proportions from any standard amount of ventilation, and then *increase* the gross quantity, where there are rise and dip splits, supposing the air in the returns to be hotter and less dense than in the intakes in each case. If, however, the returns were so mixed with carbonic acid gas and so cool as to be more dense than the air in the intakes, then the reverse results would ensue on increasing or reducing the ventilating pressure, where the splits are not level. We had a long discussion about this at the North of England Institute of Mining Engineers. Some one suggested, after the Lundhill accident, that instead of having air kept so much in one current, if they had taken it up each bank on separate splits, they would have got a much better ventilation; but the objection was raised that in the event of the furnaces being low and the general ventilation being reduced, the far-off places would get no air; it would all run through the "short cuts;" and it was to correct that idea that the matter was made the subject of investigation by careful experiments. Further, the benefit of splitting air depends in a great measure upon the proportion of resistance that occurs in the shafts as compared with that which occurs in the workings. The total pressure applied may be divided into two separate items, one of which is employed to overcome the shaft friction, and the other to overcome the resistance in the workings. Generally speaking, you can subdivide the workings till you reduce the friction very materially; but the friction in the shaft is, of course, always the same for a given quantity of air, and it is only from reducing the friction in the workings, that the beneficial results of splitting the air are derived. As to dumb drifts, in some collieries, where discharges of gas occur, it might be expedient to use them; but he would rather have sweeping ventilation, as a rule, and a mixing of the return air from the place where the gas was given off with that from the other ways, so as to render it safe before reaching the furnace. If you supply the furnace with fresh air, you never get with the same furnace the same amount of air into the workings, and our object is to cut down the amount of friction in the downcast and upcast shafts. There is one rare case where that does not hold, and that is if your returns were so charged with carbonic acid gas, so fearfully charged with it, that they would not let the furnace burn, you would have nothing else for it but to use fresh air, but you would use it at the expense of not getting the same amount of ventilation as you would get with ordinary air.

It may not be generally known that the highest points of the chain of the Andes are sinking. In 1745, when measured by La Condamine, Quito was found to be 9,596 ft. above the sea. Humboldt, in 1803, found it had fallen to 9,570 ft.; Boussingault, in 1831, was astonished to find it was only 9,567 ft.; Orton, in 1867, found it reduced to 9,520 ft.; while, finally, Reiss and Stubel verified that in 1870 it had shrunk to only 9,356 ft. above the sea-level. Quito, therefore, has sunk 240 ft. in 125 years.

THE HOTCHKISS REVOLVING CANNON.

BY PARK BENJAMIN.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

DURING the last three years scattered and incomplete reports regarding the performances of the new Hotchkiss revolving cannon have appeared from time to time in the European scientific and military journals. Derived, as these mainly were, from unofficial sources, and tinged more or less with individual expressions of opinion, they have lacked that perspicacity which would enable the reader unconversant with the weapon to form an intelligent and fair idea of its efficiency, both intrinsically and as compared with other and kindred arms. Experiments, mainly under the auspices of the French government, have been continued up to as late as July last; so that the results obtained from the official reports of all the trials are now for the first time, as a whole, laid before the public.

To those unfamiliar with the weapon a brief description of the principles governing, as well as the details of its construction, may not prove unacceptable. The gun is not a mitrailleuse, according to the common understanding of that term. It is to be sure a bundle of barrels, rotated by suitable mechanism, which discharge a hail of projectiles; but the former, instead of having bores of the size of those of small arms, are an assemblage of rifle cannon of 37 millimetres calibre; and the missiles are conical percussion shell, weighing 507 grams each, and made up as fixed ammunition with metallic cartridges charged with from 100 to 110 grams of powder.

The barrels are of cast steel, five in number, and are grouped in a frame about a central shaft, through the rotation of which they are turned about it as an axis. Inside the breech, and fastened to the extremity of this shaft, is a disk, the rear face of which is provided with ducts, which enter the grooves of a worm-wheel which is mounted on a shaft extending transverse the breech portion. It is clear that if, by a crank on the outside, the transverse shaft be turned, then, through its worm-wheel and the spur disk, the axial shaft of the barrels will be rotated. The groove on the worm-wheel is so cut that for an instant of its revolution the spur disk, and consequently the barrels, are left motionless. At this instant the firing takes place.

From the transverse shaft motion is imparted to all the rest of the machinery. The bearing of the left hand end is inside the breech, and at the extremity of the shaft therein enclosed is a short arm at right angles. This carries a pin which, working in a slotted piece, gives the latter a to-and-fro motion when the turning crank outside is revolved. The slotted piece moves a rack, the rack through a pinion another rack; and the last is connected with a small piston which through this mechanism is made to travel forward and back in a conducting trough. Just above the trough, and opening into it, is a door which, when the piston is drawn back, falls open, allowing a cartridge to slide down an inclined plane above and into the trough. The piston then travels forward, drives the charge into the barrel, which stops for an instant in front of the passage, and at the same time a stud on the upper part of the piston pushes the feed door shut. We mentioned above two racks, one of which carries the loading piston already described. The mechanism is such that as one rack travels forward the other, which is underneath, runs back, and *vice versa.* The object of the lower rack is to carry a hook-shaped extractor, which, when pushed forward, catches in the rear rim of the spent cartridge shell which happens to be in the barrel immediately adjacent. As the shell is drawn out it strikes an ejector, and is thus thrown to the ground through an opening in the breech-block.

The new cartridge is now pushed in by the piston for its entire length, but its end is left slightly protruding in view of an inclined plane which is cut in the metal of the breech, and which completes the forcing in of the load as the barrels are turned.

While all of the above mechanism is located in the left of the breech, the firing apparatus is arranged at the right. On the transverse shaft, the same above mentioned as worked by the outside crank, is a cam which, as the shaft is revolved, pushes back an arm connecting with a spring firing-pin, thus cocking the piece. When, however, the loaded barrel arrives opposite the end of the pin, the cam-shoulder slips from under the arm, the pin is driven forward by its spiral spring, and the charge is exploded.

It is, of course, impossible to follow the operation of these parts in detail without the aid of drawings; but from the preceding the reader will be enabled to form a fair general idea of the simplicity of the mechanism. The projectile, as before intimated, is a conical shell, the fuse of which consists of a case which in its under part contains a lead plunger with a brass envelope. The plunger holds the fulminate, and has a small powder chamber. It is fastened by a safety plug of lead in the under hole of the fuse, and closed by a plug which has a point, against which the plunger drops at the sudden stoppage of the projectile, the concussion exploding the fulminate. There are ingenious arrangements for pointing to nice angles, the gun being placed on a saddle having trunnions fixed to the carriage. Further explanation may be now omitted in order to turn to the consideration of the reports before us.

Ballistical Results Obtained with the Hotchkiss Revolving Cannon at Gavre, France, in January, 1874.

Initial velocities measured at 25 met. distance from the muzzle. French Ripault powder; density of charge, 0.908.*

Weight of charge	100 gr.	110 gr.
Weight of projectile	507 gr.	507 gr.
Mean initial velocity	421.7 met.	432.9 met.

* Since this period some new ballistical improvements have been made on this gun; at the trials made by the French government at Bourges in June, 1874, a mean initial velocity of 458.8 met. was obtained, with 110 gr. powder, and a projectile weighing 507 gr.

The ranges at this trial were:

Elevation	2° 40′	5°	10°	15°
Range in met	1,003	1,723	2,842	3,460
Elevation	20°	25°	30°	35°
Range in met	3,916	4,240	4,580	4,700

Range, Deflection, and Deviation; weight of projectile, 507 gr.; charge, 100 gr., Ripault powder.

Total angle of elevation	34° 47′
Velocity of wind, parallel to line of fire	3.1 met.*
Velocity of wind, perpendicular to do.	1.1 met.†
Density of air	1.247
Mean range	4,014 met.
Mean deflection, to the right	32.2 met.
Mean deviation, longitudinal	25.0 met.
Mean deviation, lateral	1.5 met.
Mean angular deviation (in minutes)	0′ 14″
Mean deviation in velocity	0.0114 met.

From the above table it will be seen that the accuracy of fire is more remarkable than has been known to have been obtained from any other gun; the proportion of the mean longitudinal deviation to the range being only 0.00623, and that of the mean lateral deviation 0.00039, while the mean variation in velocity, 0.0114 met., is practically nothing.

MAXIMUM RANGE.

The maximum range of the Hotchkiss revolving cannon of the model of 1874, with a projectile weighing 520 gr., and a charge of 120 gr., is about 5,000 met. The corresponding angle of elevation is 35°.

BURSTING OF THE PROJECTILES.

A number of projectiles charged with 25 gr. of musket powder were burst by means of electricity in a wooden box measuring one cubic metre filled with wet sand, so that all the fragments were obtained after the explosion.

The average number of fragments from each projectile were fifteen of iron, three of the brass coating, and the fuse, comprising:

Three pieces weighing between	100 gr.	and	50 gr.
Five " " "	50 gr.	"	25 gr.
Eleven " " "	25 gr.	"	10 gr.

SENSITIVENESS AND GENERAL ACTION OF THE PERCUSSION FUSE.

At the trial of the revolving cannon at Gavre several shots were fired into the sea at angles of 2′, + 15′, + 2°, + 3°, + 5°, and all the projectiles burst on striking the water.

Twenty-five fuses were fired at different angles from 20° to 34° 47′, and no missfire occurred.

* From ahead. † From right.

At a trial in Romania in July, 1874, three hundred and twenty shots were fired, at elevations from 3° to 6° 30′, and no fuse was found which had not acted properly.

PENETRATION OF THE PROJECTILES.

The gun was placed at 150 met. distance, before a target of oak 12 cm. thick. Three shots were fired, all penetrating the target, the first shot bursting a few metres behind it. The second shot burst 400 met., and the third shot 300 met., behind the target after having struck the ground.

Three shots were fired against a cast-steel plate 10 mm. thick, at the same distance of 150 met. from the gun. The first two shots penetrated the plate, and burst a few metres behind it. The third shot, which was directed against an oak framework 25 cm. thick, to which the plate was fastened, penetrated the latter, and burst inside the wood, tearing and splitting it about 1,200 mm. in length.

GENERAL REMARKS ON THE SYSTEM.

On thus examining the results obtained by the revolving cannon, it is found to be an arm of very superior capacity and of well calculated proportions. The power of the powder is utilized in a high degree; for, with a projectile weighing 520 gr., and with a charge of about one-fifth, there results an initial velocity of 458 met., and a range of about 5,000 met.—an effect which only recently has been obtained with regular field artillery; while the precision of the fire in both range and direction is remarkable in the greatest degree, surpassing anything that has been obtained up to the present time.

The trajectory of the gun is, for an effective range, low, and a very precise, rapid, and effective fire can be kept up at a range of 4,000 met., corresponding with an elevation of 20°.

This machine-gun has, besides its great accuracy and range, the peculiar and valuable advantage of firing explosive projectiles, producing the greatest moral and physical damage to the enemy, and enabling the gunner at the same time to rectify its fire by observing the explosions of falling missiles.

As there is no recoil and no change of direction during the fire, the gun, once laid, will continue to throw from *sixty to eighty explosive shells per minute*, at ranges approaching to those of field artillery, on the same spot, or on various points of line requiring the same elevation, without any further operations than those of supplying the gun with cartridges, turning the crank, and regulating the lateral adjustment.

The essentially mechanical arrangement of the system is simple and compact; the working parts are strong, and of simple form, and they are all encased within the solid breech, and not one of them is exposed to the shock of discharge.

The brass coating of the projectiles affords an excellent bearing for the grooves of the rifling, and at the same time obviates the difficulties of leading and fouling of the bore, while the saw or tooth-like grooves cut into it reduce the friction to the greatest possible extent, thus giving a satisfactory velocity with a minimum of strain on the gun.

The metallic cartridge always produces an absolutely gas-tight closure of the breech.

Another feature of this arm, to be well estimated in actual service, is its facility of manipulation. The operation of loading is simple, and the gunners only require the briefest instruction—as, besides the laying of the gun, nothing is necessary but to supply it with cartridges, and to revolve the crank.

COMPARISONS OF THE RESULTS OF THE HOTCHKISS REVOLVING CANNON WITH THOSE OBTAINED BY OTHER GUNS AT GAVRE.

A part of the before-mentioned trial at Gavre in July, 1873, comprised some practice with a revolving cannon under exactly the same conditions as with four Gatling guns of different calibres, which had shortly before been under experiment by the same commission, with a view of comparing the effects of these different kinds of arms.

The guns under test were as follows:

Nature of Arm.	Weight of Projectile.	Charge.	Bursting Charge.	Weight of Gun.
36.68 mm. Revolving Cannon..........	490.00 gr.	85.00 gr.	20.00 gr.	475 kil.
25.5 mm. Gatling Gun......................	256.85 gr.	31.77 gr.	....	347 kil.
16.6 mm. " "	97.52 gr.	19.33 gr.	....	335 kil.
11 mm. " "	24.20 gr.	5.16 gr.	....	170 kil.
11 mm. Mountain Gatling................	24.20 gr.	5.16 gr.	....	64 kil.

First Experiment.—Firing against a batallion of infantry in columns, divided into three troops or companies, represented by three Targets, each 1.80 met. high, and 70 met. long, placed at distances 70 met. apart. Distance of all guns from the first target, 1,650 met.

TABLE I.

Nature of arm.	Angle of Elevation.	Number of Rounds Fired.	Expenditure of Ammunition in Kil.	Number of Hits.			Total Number of Hits.	Percentage of Hits.	Number of Hits per Kil. of Expended Ammunition.	Effective Power.
				1st Target.	2d Target.	3d Target.				
36.68 mm. Revolving Cannon...	6° 36′	80	53.6	3	39	13	55	70	1.04	36.40
11 mm. Gatling Gun.........	8° 25′	400	15.7	19	24	2	45	11.25	2.85	26.32
11 mm. Mountain Gatling....	10° 15′	435	17.1	6	10	0	16	3.70	0.89	8.62

The superiority of the revolving cannon is here well marked.

Second Experiment.—Firing against a batallion of infantry in columns, divided into platoons, represented by six Targets, each 1.80 met. high, and 35 met. long, placed 35 met. distance apart. Distance of all guns from first target, 1,795 met.

TABLE II.

Nature of Arm.	Angle of Elevation.	Number of Rounds Fired.	Expenditure of Ammunition in Kil.	Number of Hits.						Total Number of Hits.	Percentage of Hits.	Number of Hits per Kil. of Ammunition Expended.	Effective Power.
				1st Target.	2d Target.	3d Target.	4th Target.	5th Target.	6th Target.				
36.68 mm. Revolving Cannon.	6° 30′	80	53.6	2	49	42	25	20	1	139	173.7	2.59	90.32
25.5 mm. Gatling Gun......	6° 1′	300	113.4	12	76	66	12	3	3	172	57.33	1.45	33.82
16.6 mm. Gatling Gun......	6° 14′	216	36.5	3	6	6	20	5	1	41	18.9	0.90	31.49

In this case, also, the revolving cannon in results much surpasses the other guns.

By the aid of extracts from the "Official Report on Competitive Experiments of the Montigny Mitrailleuse and Gatling Guns, at Shoeburyness, in August and

September, 1870," there are means of making a comparison of the Hotchkiss revolving cannon with the guns under consideration in that trial.

The following tables comprise the practice at ranges of 1,280 met. and 1,890 met., as a comparison can only be then made if the ranges and other circumstances do not differ largely from each other.

TRIALS AT SHOEBURYNESS IN 1870.

FIRST EXPERIMENT.—Firing against a column of targets 16.44 met. long, representing 90 infantry, divided into three troops or companies 18.30 met. apart. Distance of all guns from first target, 1,280 met. Time of firing, two minutes.

TABLE III.

NATURE OF ARM.	Number of Rounds Fired.	Number of Hits.	Percentage of Hits.
25.5 mm. Gatling Gun............. ..	255	99	38
16.6 mm. " "	239	236	98
11 mm. " "	545	104	19
Montigny Mitrailleuse.................	272	68	24

SECOND EXPERIMENT.—Firing against a column of targets 8.22 met. long, representing 45 infantry, divided into three troops or companies 27 met. apart. Distance of all guns from first target, 1,890 met. Time of firing two minutes.

TABLE IV.

NATURE OF ARM.	Number of Rounds Fired.	Number of Hits.	Percentage of Hits.
25.5 mm. Gatling Gun.................	238	99	41
16 mm. " "	338	164	48

CONCLUSIONS FROM THE FOREGOING.

In comparing the results obtained in Table I., we find that the number of hits per 100 shots fired from the revolving cannon, during an equal length of time, are six times greater that those obtained with the 11 mm. Gatling gun, and twenty times greater than with the 13 mm. Mountain Gatling.

The number of hits per kil. of expended ammunition is less for the revolving cannon than for the Field Gatling, but more than for the Mountain Gatling, while the effective power* is:

For the Revolving Cannon.........36.40
For the Field Gatling...............26.32
For the Mountain Gatling.......... 8.62

In Table II. the percentage of hits of the revolving cannon is three times higher than of the 25.5 mm. Gatling, and nine times higher than that of the 16.6 mm. Gatling, and the number of hits per kil. of expended ammunition is nearly double those obtained with the 25.5 mm., and nearly three times that of the 16.6 mm. Gatling. The effective powers are:

For the Revolving Cannon.........90.32
For the 25.5 mm. Gatling... ......33.82
For the 16.6 mm. Gatling..........31.49

* By the effective power of an arm is understood the compound quality which is governed by the number of hits on the targets, the line of firing, the distance the targets are placed from the gun, and the dimensions of these targets.

In the determination of the effective power, there are, besides the unit of time, two quantities, which are fixed by the conditions of the practice, viz.: the range and the dimensions of the targets. As these are chosen analogically to the circumstances under which the arms to be tested are subjected in actual service, we have the means of comparing different kinds of arms under the practical conditions they are employed in; for example, in Table II. is understood by effective power, the number of hits made in a minute of time by a gun on six targets 1.80 met. high and 35 met. long, placed 35 met. distance apart; distance of gun from first target, 1,795 met. This definition of effective power is used by the French artilleries, and, in the present case is taken out of the "Memorial de l'Artillerie de la Marine" (2de livraison, 1874), where the comparative trials of the Hotchkiss revolving cannon with the Gatling Mitrailleuses are reported.

Observe that the effective power under the above stated conditions affords no judgment of the weight of ammunition expended, and as there are certain cases where it is not only important to know what effect can be produced with an arm, but what quantity of ammunition it requires to produce this effect, it is necessary to compare these two figures with each other, and we can thus form a true judgment of the merits of the different arms.

That is to say, in this case the revolving cannon obtained an effect three times as destructive as the Gatling guns, with an expenditure of half the weight of ammunition.

Comparing the number of hits per cent. of the guns in Tables III. and IV., with the revolving cannon in Tables I. and II., the number of hits is higher for the revolving cannon than for all other guns.

Note the line of firing in Tables I. and II. was one minute, while the lines of firing in Tables III. and IV. were two minutes; so that, considering the time of firing, the number of hits is much greater for the revolving cannon than for the other guns.

It must also be remarked that these results were obtained with a revolving cannon of the first model, built in 1871, of inferior ballistical capacity, with a projectile weighing 490 gr. and a charge of 85 gr. Since this time the inventor, M. B. B. Hotchkiss, has, from his own experience, and according to some valuable suggestions and indications made by the committee of experiments at Gavre, augmented the power of his arm, so that there is reason to expect from the guns of most recent date, using a projectile of 520 gr. and a charge of 120 gr., results much superior to those obtained at Gavre in January, 1873; and it is to be regretted that sufficient data for making a comparison of the effects obtained with the latest models did not exist.

Judging from the general results, it may be concluded that the Hotchkiss revolving cannon is in most respects superior to and can be used with greater advantage than any other arm tested in the tables from I. to IV.

For all purposes of defence, or on open ground, at ranges approaching field artillery, for damaging material, and reaching troops behind cover, for the employment in advanced trenches or field-works, and for repelling cavalry attacks and assaults on forts, the arm will be a formidable one. This gun may be applied for offensive purposes in nearly all cases where light artillery can be advantageously used. It is, besides, a valuable weapon for marine use, when placed on the decks of ships, or for arming boats, and for landing purposes.

For the last-named purposes, where it is not necessary that the gun should be absolutely without recoil, a lighter model is manufactured, its weight being only about 300 kil.

In the Hotchkiss revolving cannon the advantages of the mitrailleuse are combined with the long ranges, precision, and moral effect of the *explosive shells of artillery*. The projectiles have, also, to a certain extent, the penetrating power of the same.

The superiority of the revolving cannon over mitrailleuses becomes the more remarkable the greater the distance at which it is used; while for ranges up to 250 or 300 met., and for purposes of flank defence, canister shot also are used with success.

The system of the Hotchkiss revolving cannon is not restricted to any particular calibre; it can be constructed either as a mitrailleuse, which employs small-arm ammunition, or of calibre much larger than the before-described gun; thereby affording the advantage of uniformity in the system of armament.

Two essentially different calibres besides the 37 mm. calibre revolving cannon are now manufactured—the one is known as the "Hotchkiss mitrailleuse," 16 milimetres calibre, and another gun designed especially for use in forts or fortified positions, this latter with a calibre of 52 mm. and a projectile weighing 2.5 kil.

Whatever may be in store for our coal beds in England, we need not despair of a plentiful supply of the useful mineral when the Chinese fields are fully developed. In Sze-Chuen, coal occupies an area of 100,000 square miles. Starting from the great plain of China on the west, there is a plateau of coal, overlying a limestone formation, extending to Shersi and Kansu for a distance of about two hundred miles. These beds lie horizontally, have an average thickness of 30 feet, and an area of 30,000 miles. According to Baron Richtofer, to whom we are indebted for the preceding information, the coal is of excellent quality. We hope, however, that no one will waste one ounce of coals because we may get a supply at some distant day from China.

MINERAL RESOURCES OF BOLIVIA.

From the "London Mining Journal."

The absolute necessity for the ready means of transport, in order to render the development of the mineral and general industrial resources of a country profitable, was probably never more clearly shown than in the case of Bolivia, whose rich deposits of minerals, and enormous natural productions, remain comparatively worthless, owing to the absence of any facilities whatever for getting the produce to the coast, or materials to the mines. To enable capitalists thoroughly to comprehend the requirements of Bolivia, and provide for them with advantage to themselves, Mr. Avelino Aramayo prepared a careful history of Bolivian industry and commerce, and he has reprinted extracts from his book in consequence of the increased interest now felt in the country. After visits for many years to Europe and America, connected with industrial and commercial matters, Mr. Aramayo ultimately devoted himself to mining affairs, these being the principal occupations in Bolivia, and at a period when this branch of industry was in general decay. He proposed to advance mining operations by improving the modes of working, and after 12 years of constant application he succeeded in stimulating progress in two of the undertakings with which he was connected, by showing the cause of their backwardness; still, mining in general continues in a depressed state. The careful study he made of the old system, the obstacles he encountered to establish the new, with the daily discoveries of mines, showed to him that the main cause of the want of success was that the mines existed so far in the interior, and in the want of roads and connection with the commercial world. He concluded that to extricate mining from such an unsatisfactory state, it was at least necessary to have a railway from the Pacific Coast to the interior.

It is to mineral industry, in Mr. Aramayo's opinion, that the Bolivians should dedicate themselves, for the reason that it is the best adapted to their territory, naturally so metalliferous, to their inland situation, to their present industrial and economic position, and that it is also in conformity with their historical traditions. He remarks that the mines that in former times have produced immense wealth are at present in the most abject state of depression. In 1846 they had 10,200 mines of silver and gold, of which only 200 were in work, and 10,000 abandoned; and from 1846 to the present time the yield has gradually decreased, so that excepting a very few miners who have been fortunate enough to come upon a vein of metal of extraordinary richness, all the rest are in a miserable position, and the best arranged enterprises soon decay and go to ruin. Mr. Aramayo has undertaken the task of explaining the cause of this, and suggesting means for its removal. They have a large number of mines, and with most extensive veins; of these in olden times only a few have been worked to a certain depth, and are untouched below, where ore exists in abundance and of superior quality; the proper working of these would give incalculable wealth. The geological character of the hills and mountains is essentially metallic, and, if we except some few, the formation of recent origin, and caused by partial and isolated cataclysms, all the rest carry with them more or less abundance of gold and silver, or at least of copper, lead, tin, and iron. Not without foundation is it believed that the great chain of the Andes, running through Bolivia in various directions, is in great part metalliferous, and has hidden in its depths virgin deposits of gold and silver, which some day will give the world immense wealth. Taking into account the opinions of the old miners, as well as his own observations, it is obvious that they did not penetrate sufficiently in depth, limiting their explorations to little distance from the surface, and abandoning one rich mine for another the moment they met with the slightest obstacle.

It cannot be denied that the old miners wanted the most common and indispensable knowledge for the exercise of their industry; nor could it have been otherwise, for at the time of the Spanish conquest, and even afterwards, they had the most imperfect information of mechanics and geometry, sciences on the principles of which are founded the operations of mining, or the art of discovering where the metals are to be met with. In working the veins they kept to no rules, nor followed any part of art, nor practised any preliminary operation which would have prolonged the duration of the mine, or saved expense in extracting the ore or the water. It is to be observed, too, that at no period was there employed larger capital in mining with the object of assuring permanent production. Of the great sums the Spanish Government expended in the construction of the lakes of Potosi, the Mint, and the royal socavon, or adit, there never was set apart any considerable amount for the encouragement of one undertaking with views for the future. The miners on their own account have worked the mines as well as they were able, some being ruined, others obtaining profits, but the general result has been disastrous, as can be well understood, on account of the small capital employed, and by miners so little experienced in the business of risk. Without a centre of help or combination to sustain them, and for want of union, they have gone on disappearing. Mr. Aramayo remarks that there are nearly 2,000,000 of Indians, of whom at most 10,000 are employed in mining, and that there can be obtained as many workmen as may be required whenever the progress of mining is enabled to offer labor better conditions. The Government monopoly of silver bullion has ceased, so that the facilities for profitable mining are increased. By the law of Sept. 11, 1872, the exportation of silver from Bolivia is free. As to the want of security in Bolivia which is supposed to exist, owing to the instability of the Government, Mr. Aramayo explains that the frequency of these political convulsions has limited their action to a certain class of society making politics their business, and who live in its ups and downs; but the working class has always been reserved, and up to a certain point sheltered from their influence, and only indirectly suffering from them. There is still more in this respect, and he can say with satisfaction that Bolivia is one of those countries in the world noted for the greatest respect for property; excepting in one or another isolated case, they have no examples in their revolutions that violent hands have been laid upon personal property.

In former times when the discoveries were made, the veins of silver being found on the surface of the mountains, some in prodigious abundance of metal, others less, but all more or less rich, the facility of working gave occupation to the thousands of Indians, who at little cost gathered great heaps of ore from the vein they chose among many. The richer portions of the ore were worked by smelting in the guairachinas—ancient furnaces—the inferior quality was put aside until grinding mills were established. Lipez, Potosi, and Oruro were great places of mines where machinery could be established in their vicinities, and the only spots where large quantities of ores could be extracted in consequence of the facility there was of carrying it to the ingenios, or grinding mills, &c., situated at short distance from the mines. All the ores at that period were the pacos (chlorides), easily manipulated; thus machinery was only used in pulverizing the ore. Amalgamation was performed by repaso—trodden by the feet of innumerable Indian "mitayos"—forced labor. When negrillos and azufrados replaced the pacos, the works which had been erected became useless, and the treatment of ores which merely required roasting, was regarded as hopeless. The only conclusion to be drawn from Mr. Aramayo's volume is that although Bolivia is rich in minerals, they are worthless to her until she has increased facilities of transport. Without roads and railways, the Bolivian miner has no market wherein to sell his products; neither can he purchase as wanted the articles required for his works, so he is obliged to collect large quantities of all he requires in anticipation. With improved means of transport, Bolivia will be able to supply not only gold and silver, but copper, tin, and other metals also, and the time is evidently fast approaching when it will form a favorable field for the enterprise of British capitalists.

THE APPLICATION OF THERMO-CHEMICAL THEORIES TO GUNPOWDER.

(Abstract from "Iron" of paper by M. CASTAN, in the "Revue d' Artillerie.")

CHEMICAL combinations, in their formation, liberate or absorb a certain quantity of work, which may, in general, be estimated in the state of heat. The union of hydrogen, of carbon of potassium, with oxygen, liberate respectively 34,500, 47,000, 62,000 calories per equivalent of the products formed; the union of chlorine with nitrogen, and that of sulphur with carbon, absorb, on the other hand, 55,000 and 24,500 calories per equivalent of these substances combined. The universal principle of the equality between action and re-action governs this order of phenomena, like all those of matter. So it is necessary to expend a certain quantity of work, to resolve water, carbonic acid, and potash, into their elements; while the decomposition of chloride of nitrogen and of sulphide of carbon, on the other hand, liberates it. The study of the union of substances and its laws, from this point of view, forms the science of thermo-chemistry.

We may divide explosive bodies or mixtures into three classes: 1. A mixture of substances the sudden combination of which, under certain influences, liberates work. (Type: detonating mixtures). 2. A combination that has absorbed work in its formation, and may restore it rapidly in its return to its primitive elements. (Type: chloride of nitrogen). 3. A mixture or a group of elements belonging to these two classes. (Types: gunpowder, in which the charcoal, sulphur, and saltpetre emit work in forming new combinations, which are rapidly produced by the liberation of the work stored up in nitric acid, gun-cotton, picrate, &c.)

The application, then, of thermo-chemistry to explosive bodies, enables us, knowing the heat of formation of all the combinations composing them, and that of the products of final decomposition, to calculate the work stored up in these bodies, and the total work which they can emit. We may thus be able to classify explosive bodies of different composition, with reference to the maximum work they can produce. But, just as in the mechanics of machines, the work received depends not only on the motor force, but also on its mode of use in the machine, so (and with greater reason) in the application of explosive bodies, from the imperfection of the receiver, it is not so much the total work stored up in these substances that has to be considered as the work which can be obtained from them in an effective manner; and it is from this point of view that we proceed to consider the powders used in war.

Influence of Proportions (*dosage*).—The work contained in a powder is merely a function of its ingredient proportions, which may vary within limits wider than those of convenient ballistic application. Yet, if we consider the proportions actually adopted by manufacturing authorities, we find they vary little from each other, and it is not without reason; the question of conservation and hardness of grain tends to bring down the proportion of charcoal and increase that of the sulphur, which, in its turn, is limited by the dirtying of the arms. Owing to the conditions imposed by the service, the differences of work contained in the various powders will hardly reach 1,500 calories in more than 600,000 given by the detonation of 1 kilogramme of these products. This fraction of 1-40 shows that from the present point of view, the choice of a proportion of ingredients is of little importance.

Influence of Physical Properties.—The great differences observed between the effects of powders arise from their physical properties, and are especially revealed by their mode of use in guns. If powder be burnt in a close vessel, as MM. Noble and Able have done in England, it is found that all the kinds of powders which do not differ much in their proportions, but whose physical properties (density, size of grain, &c.) vary within very wide limits, give nearly the same pressure of 32 to 37 tons per square inch. The mode of trituration itself has no great influence on detonation in a closed vessel, as the observations of MM. Roux and Sarrau have proved. But if the gases can do mechanical work during detonation—that is to say, if this occurs with expansion—the influence of physical properties appears at once. Thus, in the experiment of MM. Noble and Able, if a hole be made in the vessel for escape of the gases, the powders immediately range, with reference to interior pressure, in this apparatus, as in cannons; that is to say, the increase of the density and size of the grain produce considerable diminution of the pressure. In the case of powders with the same proportion of ingredients and the same grain, but differing in the process of trituration, one is obliged to give stamped powders a density about 0.08 less than that of powders triturated three hours under millstones, in order to obtain the same effects with the same charge. Taking powders triturated in the same manner, having the same proportions and the same grain, a difference of density of 0.09 lowers the velocity more than a third, from a value of 400 to 260. These differences, one sees, are much more considerable than those arising from the most extreme variations of proportion in practice, but as they do not proceed from a difference of work stored up in the powder, but rather from varieties introduced in the utilization of this work, they can only be brought forward in evidence in the firing of guns.

Justification of the Composition of Gunpowder.—All that has been said on the secondary *role* of proportions of powder, reduced to the limits imposed by their employment, applies only to a mixture of saltpetre, sulphur, and charcoal. It is certain that by varying, not the weight, but the nature of the constituents, we may obtain very different effects, which the application of the thermochemistry of the present enables us to anticipate with sufficient distinctness.

The results of this study show that our ternary mixture is one of the least powerful explosive substances, and point to a number of bodies the substitution of which for the actual constituents would greatly augment the total work contained in the powder. But we should be constrained to such a radical change only by grave motives, and it should be shown that the powder of ordinary composition was unable to produce the effects required of it. This is what has occurred with mining powder, since the explosive properties of azotised organic compounds have been recognized. But the two cases are very different.

With powders of ordinary proportions, but the physical properties of which have been rationally studied, it has been found possible to give to projectiles weighing more than twice the weight of a full sphere of the same calibre, velocities exceeding 600 metres; the charge about a third of the weight of the projectile. By introducing certain modifications into the cannon, and, perhaps, too, into the way of setting fire to the charge, we might be able, with a larger charge, to exceed 700 metres. We are stopped in this increase of velocity, however, by considerations of ballistics, and of the service of guns; in field pieces by the maximum weight to be given to the piece and its belongings; in pieces of position, but of large calibre, by the solidity of the piece itself. We see then, that the powder of ordinary proportions leaves a large enough margin for our utilizing all the progress which may be made in the art of construction of artillery *materiel.*

For the rest, the study of powders, in all countries, has always had for its final object to hinder the powder from giving in arms the maximum of effect it can give, by retarding its combustion, and increasing, thus, as well as by the mode of charging, the capacity of volume where the gases are developed. The result of all these experiments may be thus expressed; it is preferable, both from the ballistic point of view, and that of conservation of *materiel*, to obtain a velocity by increasing the charge of powder, rather than by forcing a less charge to burn under a greater tension.

These results have only been got by physical modifications of the powder; but one can see that a change of composition could only contribute to them, on condition of presenting a diminution in the total work contained in the new motor. If, then, profiting by the aid of thermo-chemical theories, we had to choose a motor for guns, the known oxygenated compounds of nitrogen, other than nitrates, would first have to be quite eliminated, and among the nitrates the one apparently most suitable would be nitrate of potash, not only because it is the only one which, producible in large quantity, allows conservation of the powder, but also because it is the one that has liberated most heat in its formation, and so renders the powder the least violent (*brisante*).

THE ECONOMICAL LIMITS TO THE USE OF ROLLED GIRDERS.

From "The Engineer."

Examples of engineering construction, especially those of roofs, are not wanting in which a sectional area of less than 2 in. is composed of more than one bar or plate. In other words, this absurdly small sectional area as built up is a compound instead of a simple section. It can be readily understood that, insomuch as the compound or built-up section requires a certain number of rivets to unite the different bars or plates of which it is composed, and that as holes must be punched or drilled for these rivets, there is a corresponding loss of material incurred. This loss is directly proportionable to the difference between the gross and the net sectional area. For instance, if we take an angle iron 3 in. by $3\frac{1}{2}$ in., and suppose it riveted to the flanges and web of a solid-sided or plate girder by rivets $\frac{3}{4}$ in. diameter, its gross sectional area will be $2\frac{3}{4}$ in., while the net will amount to only 10 in., thus showing a loss of nearly 30 per cent. In this calculation the diameter of two rivets has been deducted, for although the rivets in the flanges and web can be designed so as to break joint in the drawing, yet when the wrappers are taken into account, and the joints, it would not be safe practically to suppose that only one rivet-hole would come in the same line of section, but allowance must be made for two. Compared at first sight with the built-up section, the rolled joist has the advantage of dispensing with the riveting necessary to connect the web and flanges, since these are rolled all in one piece, and there is consequently no loss of sectional area. It would be more correct to say there is no loss of material due to rivet holes, for it will be seen that there is in larger examples considerable loss of sectional area both in the web and flanges.

A rolled joist is essentialy a girder with parallel horizontal flanges, since in the process of rolling the depth cannot be altered. We are not putting any limits at present to the depth or the length of the joist, although practically the limits would be soon arrived at. Our object is to point out that were the capabilities of the rolling mill unlimited in this respect, there would nevertheless be a certain span and load beyond which the employment of rolled joists becomes wasteful of material. Besides the uniformity of depth which must prevail in a rolled girder, the sectional area must also be maintained constant, since neither the width of the flanges nor their thickness can be varied, nor the thickness of the web. So far as a span of twenty feet is concerned, or under, it is of no consequence whether any of these dimensions are varied or not; but when this span is surpassed some greater coincidence between the theoretical and actual sectional areas of the girder at different points becomes absolutely necessary if economy in construction is of any moment. Theory dictates that in every girder which is subject to the ordinary conditions attendant upon these structures, either the depth or the sectional area must vary. It is in many instances immaterial in which of these dimensions the alteration is made, but one or the other must undergo it. The depth may be maintained constant provided the sectional area is diminished towards the ends of the girders in proportion to the strain; or the sectional area may be maintained constant, or very nearly so, if the depth be decreased towards the same points. The fulfilment of the former conditions gives the correctly designed parallel girder, and of the latter the bowstring. Neither of these forms can be produced from the rolls. It is true—and the advocates for the employment of rolled joists lay great stress upon the assertion—that an unscientific approximation can be made to the former of these types, not by diminishing the sectional area towards the ends, but increasing it by the use of extra plates riveted to the flanges towards the central part of the girder, which amounts to much the same thing. But, allowing that this increase of section can be obtained in this manner, the minimum or rolled section of the flange must still be constant, both in breadth and thickness. Moreover, when extra plates are riveted to the flanges in order to give an increased sectional area at the centre, the principle of the rolled joist is at once departed from, and it becomes, to all intents and purposes, a built-up girder, without possessing the advantages of that particular form.

It is not only in the flanges that a loss of metal occurs from the impossibility of varying their section, and also in consequence of their depth being uniform, but the web suffers as well. As the girder becomes longer so must its depth be increased, a condition which cannot be practically fulfilled without at the same time increasing its thickness. This latter dimension will be constant throughout the whole girder. Theoretically, with a uniformly distributed load, the strain upon the web of a girder at its centre is *nil*, and even with a rolling load of the same intensity per foot run its amount is not of much consequence. Rolled girders are more frequently employed to support uniformly distributed than moving loads. Consequently, the strain upon the web is nothing at the centre, and a maximum at the ends. The shearing strain at the ends is equal to one-half the total distributed load. Thus the sectional area of the web at the ends must be sufficient to resist this strain, and by the conditions of manufacture it must be constant throughout the girder, although theoretically the strain diminishes to zero at the centre. There is no need of pointing out the enormous loss of material which would occur in a girder of any pretensions to size, supporting a load of any consequence. This disproportion between the sectional area of the webs of rolled girders and the strains upon them must always remain, since the method which can be employed to vary the area of the flanges cannot be applied to the web. Theoretically, as the sectional area of the web must be proportioned to resist the maximum strain upon it, the loss of material in this respect is exactly 50 per cent. Practically it would not amount to quite so much as this, because there must of necessity be some material in the central portion of the web, but still the excess would be very considerable.

It will be conceded that the strongest girder is that which with a given weight of material will bear the greatest load under precisely similar conditions. Let us compare in this respect the rolled and the built-up girder, and as a datum to start from, let the span be 20 ft. and the depth 1 ft., which is not far from the limit of depth hitherto attained in the rolled section. Commencing with the flanges, it is obvious that since the net sectional area of both must be equal in either to withstand the same strain, the advantage lies on the side of the rolled girder, because the gross sectional area of its flanges is equal to the net area. There is no loss of material due to the connection of web and flanges. The built-up girder, on the contrary, is subject to a certain amount of loss due to the difference between the gross and net area of its flanges, and consequently the weight of material in the flanges must exceed that in those of the rolled girder in order to afford the same net sectional area. With a given net sectional area, therefore, the flanges of a rolled girder will be lighter than those of a built-up one. But, if the comparison be carried further, it will be found that what the built-up girder loses with regard to the flanges it will more than gain with respect to the web. In the example selected, taken from a trade circular, the thickness of the web of the rolled section is $\frac{9}{16}$ in., whereas in a built-up girder of the same area of flange and depth, $\frac{1}{4}$ in. is more than sufficient. Besides, the thickness of the web of a rolled girder must increase with even a very small increase of the depth, and must, moreover, be uniform throughout the entire girder; but this is not the case with the web of the built-up section. The thickness of the web of a plate girder, which is always in excess of the requirements of theory, need not be increased until the depth is nearly doubled. A few additional stiffeners are all that are necessary to give rigidity to the greater depth of the web.

In connection with the subject of the relative strength of the type of two girders under consideration of the same total weight, it must not be lost sight of that the strength of a girder of any form does not depend exclusively upon the actual sectional area of either the flanges or the web, but is due in equal measure to the observance of the proper proportions between the span, the depth, and the breadth of flange. These nice adjustments are easily insured in the case of the built-up girder, but not in that of its rolled fellow. It is here that the former has an immense advantage over the latter, particularly when the dimension of the span exceeds 20 ft. The proper theoretical ratio between the various parts of a girder cannot be observed in those of the rolled form. Hence, in comparing a rolled and a built-up girder under the same conditions of loading and weight, the weight of the flanges of the latter can be decreased by increasing the depth without at the same time augmenting the weight of the girder in the same proportion. Briefly, the great difference between the two is that a built-up girder can be designed so that the dictates of theory can be very closely adhered to in practice, and a rolled girder cannot. The form and proportions of a built-up girder are the result of theory, those of the rolled section the result of practice. The exigencies of the manufacturing process virtually determine the relative proportions of a rolled girder. Some attempt is made to assimilate these to what theory would indicate as the correct proportions, but with very equivocal success. It is in fact not possible to roll a girder with a proper regard to these theoretical requirements.

Summing up the subject, it would appear that in the comparison we have instituted, when the span does not exceed from 10 ft. to 20 ft., a rolled girder will be cheaper than a built-up section, for although there may be a superfluity of metal in a part of it, yet the price per ton will be less than for built-up sections. When this limit is surpassed the weight of the built-up girder of the same span and depth will be slightly less than that of the rolled girder. This supposes the ratio of depth to span not to be that which is calculated to give the greatest amount of strength. If the built-up girder be correctly proportioned, so as to reduce the strains to a minimum, it will be cheaper than the riveted section for a span greater than that already alluded to. The riveting together of a couple of rolled girders longitudinally, so as to double the depth, is a handy expedient as a makeshift, but in complete defiance of all theory. The material in the two flanges, which is then concentrated in the middle of the web, is so much waste metal, since it is situated at or near the neutral axis of the whole girder, and its leverage for resisting strains is reduced to a minimum. Other ingenious combinations of rolled girders are sometimes made. For example, two or more are placed side by side and united by horizontal plates riveted over the top and bottom flanges. This arrangement possesses all the disadvantages of the old box girder, which is now obsolete. It is quite impossible to get at the inside after the plates are once put together, and the same remark applies to the combination of rolled joists with regard to the spaces between the parallel girders. While, under certain circumstances, and within certain limits, rolled girders are exceedingly well adapted for constructive purposes, and could be employed to advantage by engineers to a much greater extent than they are; yet, whenever a girder is required to fulfil certain conditions which admit of a theoretical adjustment of sectional area of strain, they will not be found economical. In a word, if a girder of small span is required to be merely adapted to a given load, one or other of the ordinary rolled sections will be found to be both convenient and economical. But if the span and load are of sufficient importance as to call for a design, the built-up girder, either rolled or open webbed, is the only proper type to adopt.

Herren Behum and Wagner have recently published their measurements of the earth. According to them, the length of the polar axis is 12,712,136 metres; that of the maximum diameter being 12,756,588 metres, the minimum 12,752,701 metres. The circumference is on the shortest meridian 40,000,098, and on the longest 40,069,903 metres.

THE POLLUTION OF RIVERS.

From "The Journal of the Society of Arts."

An important conference was held last month by the Society of Arts on the subject of "The steps to be taken to ensure prompt and efficient measures for preventing the pollution of rivers." The views expressed and the discussions following are herewith given:

The Chairman, in opening the proceedings, said that the papers which had been circulated in the room describing the various methods proposed for dealing with the difficulty would be taken as read, and he therefore proposed to take the discussion in the following order: 1. Existing evils and necessity of remedy. 2. Separation of fæcal matters, manufacturing refuse, and house drainage from the rain-fall. 3. Methods of treating water-carried sewage so as to purify it before discharging it into rivers. To each of these points an hour would be allotted.

Mr. J. Chalmers Morton (one of the Rivers Pollution Commissioners) submitted that processes having been already pointed out, and being well known by which filthy water can be cleansed, and by which therefore river pollution, in almost all its forms, can be prevented, it was no longer a solution of the once inscrutable problem that was required; it was a plain and workable law which shall forbid it that was needed. Law no doubt already existed for the abatement of river nuisances, so that if any one be aggrieved he has his remedy at present, and if he has a nature tough enough, purse and patience large enough, he may even now obtain the injunction he desires. But the practical value of the existing law may be safely gathered from the existing condition of our rivers. The existing law was virtually inoperative, and it was to the enactment of an efficient law that all our attention should be now given. The existing failure of the law against river pollution was owing partly to the costliness of its processes, but mainly to the indefiniteness of the offence which it is desired to prevent. He had always understood that a plain and unmistakable definition of a nuisance or offence was the very first step to be taken in any attempt to forbid it or abate it, and therefore he heartily hoped that this conference might see its way to the urgent and confident recommendation of the enactment of unmistakable standards of impurity, below which all liquid discharges into water courses shall be forbidden, as an essential part of any serviceable legislation on this subject. Without them it might not be always impossible to obtain a conviction; but he said that without them it was impossible that justice should invariably be done, for these standards were as necessary for the protection of the innocent as for the easy conviction of the guilty. At present, if you go before a court with your complaint in general terms of the nuisance by which you are aggrieved, you are certain to be met by evidence, also in general terms, that the thing is not so bad as you declared it, or that there is really no nuisance at all, or that if there be any discomfort it is as nothing compared with the tenfold injury which would be inflicted on one hundredfold the number of sufferers if any injunction should be issued; and what was a distracted jury, or even a clear-sighted judge, to do for either complainant or defendant in the face of contradictory evidence, both lay and scientific, so long as both are allowed all the resources of the English language with which to attack or defend? What was wanted was a set of standards to which the case could be at once referred with no possibility of ambiguity or uncertainty as the result of the reference. Of course it was necessary that these standards be most carefully fixed, so that, in the words of the Royal Commission, "there be no serious injury to the processes and manufactures concerned." As regards the standards which have been recommended in the reports of the Rivers Commission, he, though not professionally a chemist, had felt at liberty to sign the recommendation that these standards be enacted, because, having compared with them the analysis of the effluent waters from various remedial processes, he was able to say that these standards were extremely lenient. It might surprise any gentleman who looks on this subject from the manufacturer's point of view to hear that the filthy Irwell water itself does not offend the standards of pollution of which we desire the enactment. It does not contain .2 of organic carbon nor .3 of organic nitrogen in solution in 100,000 parts. Of course it has been polluted by the access of drainage much filthier than itself, so that if these standards were enacted they would act beneficially on the Irwell; but the fact that this filthy river does not itself offend them is proof of their leniency. It might be thought a whimsical, or even fantastical thing to make, in an Act of Parliament, .0003 per cent. of organic nitrogen the definition of an offence; but we had a precedent for that kind of definition with the Alkali act; and he presumed that Dr. Lyon Playfair could ascertain and declare the presence of .3 of organic nitrogen in 100,000 parts of water, if not with as much facility, at least with as much confidence and certainty as that which he would feel, after counting hands, in declaring the minority, if any, which is prepared to defend legislation against offence without any definition of the offence it is intended to forbid. Lastly, no one had ever thought of putting these standards in the hands of the common informer. They must of course be administered by competent men appointed for the purpose. But to this, having already exhausted his allotted time, he would only advert. He earnestly desired that as one result of this conference some confident and urgent declaration might be laid before the proper Government department that the enactment of standards of forbidden pollution was essential to efficient legislation on this subject.

Major-General Scott, C. B., quite concurred in the view of the last speaker, that a standard of purity was essentially necessary before legislation could be attempted. But the principal question to be discussed would be what that standard should be. He believed that ultimately they would come to the only mode by which water when once foul could be purified, and that was either by using it in irrigation or by earth filtration. But while believing this, he also thought it would be very impolitic at the present moment for Government to legislate in such a way as to oblige every town to take up one of those two systems. In the first place land was in many places difficult to acquire, and in the next people objected to having a large amount of sodden soil in the neighborhood of their dwellings. Above all, you could not get any body of Englishmen to enforce upon landowners the necessity of having such saturated ground in their immediate neighborhood. This had been proved in the case of Birmingham. In that case almost every man who had a knowledge of the sewage question was invited to give his opinion; all the leading chemists, engineers, and agriculturists stated their views on the subject, and ultimately it was resolved to bring forward a scheme by which the separation of the solid from the liquid sewage was to be supplemented by irrigation and filtration. There was no doubt in the mind of any reasonable man that no better system than this could be proposed, but what was the result? After the bill had been approved by a select committee of the House it was thrown out, simply on the representations of two land owners principally affected by it, that it would be an injustice to them. At the present time therefore, you could not carry out complete legislation if it were attempted, and the question arose to what extent should it go. To his mind, the matter was very clear, and he would beg to read a few words written by the Sewage of Towns Commissioners, fifteen or sixteen years ago. They said "that by far the greater part of the solid matter held in suspension in water was readily deposited in rivers, covering the banks with mud and permanently raising the beds, gradually destroying the scouring power of the water, partially silting them up; and in some instances these deposits had accumulated to such extent as to impede the navigation, and render the surrounding country subject to floods, entailing a vast expenditure in periodical cleansing. And however the appearance of the water might be improved after these deposits had taken place, yet the deposited matters lay in the bed of the current under conditions favorable to putrefaction; so that when the foul mud was disturbed during the prevalence of rain or floods it sent forth effluvia very offensive to the surrounding district." Here then, it was plain that the chief evil arising from the flow of sewage into rivers was attributed to the solid matter, and the Commissioners went on to state that this "might be obviated by simply arresting the solid matter in suspension in the liquid." Inasmuch as the Legislature itself had been instrumental in bringing about the present state of things, he thought it would be very hard on towns to oblige them all, and at once, to carry their sewage water to that degree of perfection which would be implied by insisting on irrigation or careful filtration. So far however as the solids were concerned, the remedy was easy enough. It would not press hard on municipalities to compel them to keep these offensive matters out of rivers. Fifteen years ago the Sewage of Towns Commissioners reported that "the more the subject had been investigated the more convincing was the evidence that there was no town which might not, with reasonable care, and at a moderate cost, greatly mitigate the existing evils, if not wholly remove them," and their conclusion was, "in the absence of means for applying sewage to land, the modes of precipitation at command did offer remedial measures of a very satisfactory character." If that were the case, why were we at the present day still in the same condition as before, with almost every town in the kingdom casting its solid sewage matters into the rivers? It had arisen because we had in the first instance aimed too high. He thought the last degree of perfection ought ultimately to be insisted upon, but at the present moment there were so many corporate towns on the banks of rivers, contributing to their pollution, that until they could all be brought to one point, it would be very unfair that one town should be picked out and made to purify its sewage perfectly, while others were still polluting these rivers. During the last three years he had a great deal to do with town councils and had seen many of their difficulties, and this much he thought might be insisted upon, that they should remove the solids from the liquids before the latter flowed into the river, and a graduated scale might easily be devised, insisting that the amount of solid thrown into rivers should not bear more than a certain proportion to the volume of water. If that much were done, more would be sure to follow, because they could not arrest the solids without creating some degree of nuisance which would necessitate the application of deodorization. Immediately that was attempted it would be necessary to use some precipitate, and then the solids might be much more perfectly removed. One-half of dissolved organic nitrogen would also be removed by precipitation, and the whole operation conducted in an inoffensive manner. The first step to be taken therefore, in his opinion, was to insist that only a certain amount of solid per gallon of sewage be allowed to pass into a stream, and the next stage would be that deodorization should be employed. When they got to that point, it might be a question in what cases further purification should be effected by earth filtration or irrigation, and, inasmuch as precipitation, or at least subsidence, was a necessary preliminary to these operations, manifestly the steps he recommended were in the right direction, and would make further legislation easier.

Mr. John Thom, speaking as a polluter of water, did not believe that any class of the community would be more benefited by legislation on this subject than polluters of water themselves. He did not speak from any theoretical notions, but from his own experience. There had been plenty of law, but there was as yet so little certainty as to how it might be applied in any given case, that the great majority of manufacturers all stood in danger both from those below and those above them on the stream. They might be prosecuted by any one below them for a nuisance, while any one above them might set up a manufactory which would do them positive harm. If they went to the most eminent lawyers for advice they would get different opinions as to what would be the result of the proceedings. About twenty-two years ago the firm with which he was connected had a lawsuit with regard to a pollution they sent down, and which was said to be doing great damage. They lost the case, but they gained much more than it cost them from having no more pollution of the same kind from those above, in fact, it was stopped in a day, showing that any legislation preventing pollution might very readily be carried out. About eighteen years ago he commenced keeping his own pollution out of the stream, but he was immediately served with a notice from the legal adviser of his landlord to refrain from any such attempts, as it was endangering his water rights and privileges. The landlord claimed to foul the stream, and in his lease there was a clause of surrender if those rights were endangered. This showed the necessity for legislation before means could be used for keeping pollutions out of the rivers. Again, the water generally came down to his works quite black to the amount of between two and three millions of gallons daily; and from careful experiments he had ascertained that one part of this black dye water would make 10,000 parts unfit for his use, so that one part being put in by a person above him compelled him to purify 10,000 parts of water; yet from a letter which he held in his hand it appeared that the manufacturer above could keep that black dye out of the water with the greatest ease, and at a merely nominal cost, in fact, he believed it could be done with a profit. Legislation, therefore, in such a case would only give fair play to all manufacturers or polluters of water. Again, on the stream above him there were large works in course of erection, which must of necessity foul the water, and from the absence of any law upon the subject those who were erecting those works did not know what to do. They put them up at haphazard, subject to prosecution if they fouled the water, and he had no hesitation in saying that it would take from 3 to 7 per cent. on the outlay on that plant to settle their legal rights, but he was equally satisfied that with proper legislation on the subject only a half per cent. would be required to enable them to keep all foul matters out of the stream, and thus avoid doing any mischief to every one between themselves and the sea.

Sir Robert Torrens, who represented the Conservators of the River Dart, said the special grievance in the district from which he came arose from the constant starting of small mines, nine-tenths of which were got up simply for stock-jobbing purposes, not really for mining. The speculators in these schemes set up works merely to sell the mines, and the earth washed out from the crushed ores was allowed to flow into the rivers in all directions. The law enabled the Conservators to interfere and stop that process if they could show that this earthy matter actually poisoned the fish, but they were utterly powerless to check it, if, as was generally the case, it did not poison the fish, but simply deterred the salmon from coming up the rivers, and spoiled the spawning beds by depositing mud where nature had placed sand and gravel, on which alone salmon would deposit their ova. The question then arose, what means could be suggested for remedying this grievance. It appeared to him very simple, and they had practical proof of their efficiency. In the Black Forest of Germany, where mining of various kinds was carried on, before the water used in washing ores was allowed to return into the stream, it had to be passed through settling tanks, in which all the mud was deposited. The water flowed through furze bushes and things of that kind, very inexpensive, and the deposit was cleared out periodically when the tanks got too full. In almost all the cases he had in his mind in Devonshire, such tanks might be put up at a very trifling cost indeed. The managing engineer of a mine above Ashburton, on the River Dart, stated that for £150 he could put up a tank of that kind, but he demanded that the Conservators should pay the cost. Inasmuch, however, as they would have no guarantee that it would be erected, or that the speculators might not cease to use it if they paid the money, of course it could not be done. He might mention another case of a mine which had been tried once or twice, and had been shut up, having scarcely any minerals in it, but it had lately been opened again in another name in order to delude the public; the water which had lodged in it for years was pumped out, and the consequence was that it killed all the fish in the stream that flowed through Ashburton. Another mine had been started close to his own place, when the stream, which had been beautifully clear, assumed the appearance of red ink. Unfortunately the law was so doubtful, and the machinery so costly, as practically to prohibit the Conservators taking any steps to remedy this grievance. He concurred in what had fallen from a preceding speaker, that it would not be well to attempt a very large measure of relief until public opinion was sufficiently aroused upon the subject, but if a moderate measure were proposed it might perhaps be carried, such for instance, as one which would compel any parties starting a mine to deposit £500 or £1,000 as a guarantee that before turning the water into the stream they would cause it to be filtered and purified. This was a most vital question affecting the whole population, though unhappily a very small portion indeed of that population was at all alive to its importance. On the other hand there was a very compact and powerful body interested, or imagining themselves interested in opposing any such effort as they were assembled to discuss, and he should like to see subscriptions got up for the purpose of circulating information on the subject, and so instructing the public mind, for until that was done he believed it would be utterly hopeless for any private member, and almost for any Government, to attempt to carry a comprehensive measure in the face of the manufacturing and mining interests in the House of Commons. He had stood three contested elections, and had never been questioned on the subject, nor did he remember any case in which a candidate had been required to state what he would do on this most important question. He, therefore, thought the first necessity was to create such a pressure of public opinion as would lead to something being done at the next election to promote efficient legislation.

Sir John Murray desired to make a few remarks on some of the rivers in which he was deeply interested. He would first call attention to a small stream called the Sherborne, not far from Coventry, known in years past as one of the dirtiest and foulest streams in the kingdom. The sewage of Coventry ran into it, but since this had been treated in tanks, which had been built for the defecation of the sewage, it had a very different appearance. Formerly for two miles down it was almost impossible to inhale the atmosphere in its neighborhood without feeling the bad effects, and as for fish they existed but a very short time in it. How they got into the stream nobody knew, but probably they were brought in from other quarters at times of flood. Matters were very different now, for he had letters in his possession from gentlemen residing on the banks, stating that the water was exceedingly pure, and that the fish were rapidly increasing in numbers. Now, if a simple process such as that adopted at Coventry —the use of sulphate of alumina in conjunction with lime—was so successful in treating the sewage of a town of 40,000 inhabitants, the daily sewage being two millions of gallons, he thought every town and village might be required to adopt similar means, and he understood that this method yielded an effluent whose purity was above the required standard. This question was one of vital consequence to the inhabitants of the whole of Great Britain. The first consideration was certainly sanitary, the object being to obtain pure air and water; the second was agricultural, for why should they throw away a valuable manure estimated to be worth two millions per annum? and the third, which came home more to himself living near the banks of some rivers in the south of Scotland, had reference to the question of fishing. The Tweed Fishery Laws had lately been the subject of investigation, and it appeared that heavy penalties, and even imprisonment had been inflicted for years past on poor fishermen who killed a smolt or small salmon, yet at the same time corporations on the banks of those streams were allowed to destroy the fish with impunity. This certainly was not a state of things which ought to be allowed.

Major-General Synge said that since he came into the room the question had occurred to his mind why anybody objected to the pollution of rivers, and why had such a practice come into such universal existence if it deserved to meet with the unmitigated reprobation of every intelligent being living near a stream. But really they had met to try and put a stop to what might at any moment prove the most desolating plague that ever afflicted the globe. Then what position did they individually occupy so long as they contributed to the propagation of the evil? The reply suggested itself to his mind that the prelude to the abuse of anything was the ignorance of its proper use, and if the objects for which water was given to mankind were properly appreciated, he thought it would be impossible for two persons to state, as he had heard in an assembly of a similar kind to the present, that water was a thing which, under no circumstances, ought to be drunk, and that the proper thing to do with every stream was to turn your back upon it and make it a vehicle for the gravest abuses. If the value and proper use of water was appreciated, it would not be necessary to devise any elaborate or scientific process. The first thing to be borne in mind was the individual duty of every man to himself and to his neighbor; but secondly, this duty must always be taken in connection with the possibility of carrying it out, and they must therefore consider whether it was really impossible to maintain the purity of water. There was much to be said in palliation of the existing system, seeing the elaborate, ingenious, and complicated machinery which had been devised for dealing with it. He believed, however, the only sound advice with reference to turning sewage into rivers was that given some years ago in *Punch*, though on a very different subject, namely, "Don't." He disliked compulsory action, for he thought no man had a right to take his neighbor by the throat and compel him to do anything, but it would be quite possible, and perhaps a popular novelty, to go back to the Decalogue and say, You shall not murder by inflicting on your neighbor the poisonous outcome of your own person; you shall not make it a difficulty to know whether your linen has been washed in pure water, or whether every shirt you wear shall not be a source of fresh danger, and every opening you make in your room an additional means of poisoning your neighbor. He should simply take this ground. If a man chose to do anything on his own premises, it should not injure his neighbor. The details of how this might be carried out were embodied in some of the proposals which had been printed. But if they went on this simple basis of the duty of using water, and not corrupting it, and then went on to exclude all putrescible matters, they would soon arrive at a practical result.

Mr. John Evans, F. R. S., suggested that it would have been better if a fourth subject had been added with regard to the legislation to be proposed. There could be no doubt that some remedy was necessary for existing evils, but his difficulty was how that remedy should be applied so as not to act unfairly on existing classes, more especially upon manufacturers, considering that the Society, under whose auspices they were gathered, was established for the promotion of arts, manufactures, and commerce. The subject divided itself into two heads; namely, the pollutions caused by fæcal matters, and those resulting from mineral matters, the produce of ordinary manufactures. If rivers were purified to that extent that fæcal matters were excluded from them, it would be a much more simple matter to deal with the matters arising from the manufactories, but it was evident to him that though it might be desirable to have some fixed tests established, those tests should not be of precisely the same nature in all cases, but that some modification should be allowed in respect of certain classes of manufactories, and that provision should be made for those with whom it was a matter of almost absolute impossibility to carry out the remedies which might be suggested. It was all very well to say that men should be compelled to send water into a river in a state of purity, which should comply with certain tests; but in many cases where the works were situated on a limited portion of ground, or on particular levels, it became almost impossible to carry on any purifying process on a large scale. Suggestions had been made for a series of ponds, or catch pits, but how on earth was a man, limited in his ground, to adopt that system? Therefore, any measures of a compulsory nature ought to be accompanied by special provisions enabling a man to obtain the necessary means of carrying them out. If a manufacturer were driven into adopting a large system of irrigation, a man below him might bring an action against him for diverting the stream, while if he adopted a system of evaporation, he was liable to be prosecuted for a nuisance. It was by no means so simple a process that any one given plan would be applicable to all circumstances, and though he agreed that there should be some fixed standards, they should be in the first instance of the mildest character. There ought to be variations allowed in the case of particular trades and manufactures, with liberty to the public authorities to abstain from calling on any particular manufacturer to comply with them, if there were no sign of danger resulting to the stream from his works being upon it. It was not every river which was intended to be potable, and there were always considerable differences arising from the proportion between the volume of the stream and of that which flowed into it; thus a drain carrying 10 gallons a minute into a large river did not effect any material mischief, while if it discharged into a small stream it would seriously injure the purity of the water. Tidal rivers again stood on quite a different footing to others.

Sir Joseph Heron said he would propose a resolution, as he had no objection to throw upon the Government the responsibility of finding out what legislation was practicable, and he thought they could not err in bringing it under their notice. It was no use abusing local authorities for the state of their rivers so long as they were utterly powerless to act in the matter. In Manchester, however, he believed the Irwell was in a better state when it passed out of Manchester than when it came in. They had an enormous supply of water, and such an immense quantity went into the sewers that it diluted the sewage to such a large extent, as compared with the state in which sewage passed into the river above, as to considerably improve the state of the river. He protested against the abominable system of introducing water-closets into every town and village, and turning all the refuse from these closets into the sewers. He considered this was beginning at the wrong end, though unfortunately the Government had, under certain influences, coerced local bodies into the introduction of this system. The resolution he had to propose was: "That this meeting, being satisfied that it is necessary to improve the foul state of the rivers in this country, and that legislation on the subject is required, requests the Council of the Society of Arts to urge this necessity on the attention of her Majesty's Government by deputation or otherwise." He did not think it would be of much use, as suggested, to circulate pamphlets, which would only be thrown into the waste paper basket; but the moment the Government dealt with the subject, and proposed legislation, the attention of the country would be drawn to it, and some good might be done.

Sir John Murray seconded the resolution, which was at once carried unanimously.

The Chairman said they must now consider the second branch of the subject, namely, "Separation of fæcal matters, manufacturing refuse, and house drainage from the rainfall," and he would first call upon Captain Liernur, who had made some important experiments at Amsterdam and other towns in Holland, to address the meeting.

Capt. Liernur said the method of using sewers so as to carry off the rainfall, and also to remove the fæcal and other putrescible matter, was without doubt attended with many serious drawbacks. That matter was very often, if not always, the carrier of organisms having infectious properties, which were not kept in the sewer, but were apt to pollute both the air and soil of the town. The air was polluted from ventilating the sewer itself, and escaped at every rise of the sewage as affected by the rainfall. Whenever it rained after several days of dry weather, the polluting elements were passed through the pores of the brickwork by simple hydraulic pressure, and when this subsoil water rose, a stratum of air equal to the rise of water was pushed upwards, carrying these infectious elements with it. Hence, so long as infectious matter was conveyed by means of water, and carried through porous conduits which were in contact with the atmosphere, there could be no other result but that both the air and soil became contaminated with the seeds of disease. Many sewage engineers thought it was not unhealthy to live in towns the soil of which was polluted with excrement, and hence they advocated the use of rain-water sewers ventilated as much as possible. He did not know upon what hypothesis they based their theory, and he could not but think that the great increase of several kinds of zymotic diseases in towns served on this principle tended very little to support it. At any rate, Continental authorities on sanitary matters were of a different opinion; they insisted on the conveyance of any matter which might carry infection through conduits from which the escape of any fluid or any gas was absolutely impossible, and also on absolute cessation of all fluctuation in the level of the subsoil water. Hence rain-water sewers should not act as drains for waste water, and fæcal matters and household refuse should be removed separately by air-tight iron pipes, or some similar contrivance. This was also demanded by the danger created outside towns; namely, the pollution produced where sewage was discharged. The cleansing of sewage by precipitation and filtration was known to be practically impossible; nor had irrigation upon the whole been much more successful, but had shown itself only a serious additional expense, besides being a danger to the public health; hence most engineers had preferred recently to discharge sewage into the sea wherever there was a chance of so doing, and did not hesitate to construct miles of culverts for that purpose, rather than involve towns in the troubles and lawsuits which often arose in connection with sewage farming. On the other hand there was no technical or financial difficulty in the separate removal of putrescible matter, or any danger of polluting the air or soil with it. This had been proved by the works constructed by himself. They consisted of a net-work of hermetically closed iron pipes in connection with a stationary pumping engine. This collected the contents of both privy-closets and kitchen sinks, the motive power being air instead of water. This system did not prevent the use of water-closets, provided they only used water enough to keep the basin clean, for which experience showed one quart was sufficient when the closet was properly constructed. Water-closets, however, were not necessary on sanitary or æsthetic grounds. Privy closets had been constructed for the poorer classes, in which no water was employed at all, and they appeared to give every satisfaction, and it was certain that the offensive matter could be removed without the enormous dilution, which, by the method of water carriage, made its utilization for farming purposes almost impossible. The matter in question could be transported for use in the wet form as collected, or be converted into a dry substance by evaporation in vacuum pans. In the first case its value to the farmer was 3s. 6d., and in the latter from 8s. to 12s. 6d. per head per annum. There was no other method by which the utilization of sewage could become profitable, for generally speaking the disposal of the matter was as much an expense as its removal, and hence the sewage of towns involved a considerable increase of taxation, which led to an increase of house rent, and resulted in a crowding together of the working classes in still smaller rooms, and in raising the price of all necessaries of life. These resultants, however, were the reverse of sanitary, and it appeared very questionable if the sewage works, at the cost of the comfort of the poor, were really sanitary improvements at all. The separate method avoided this sort of danger; it made the collection and disposal of putrescible matters a source of profit, both possible and practicable, the result being that a town could be sewered without polluting either the soil, the air, or the stream, and without increasing taxation. This could never be effected by the pail system.

The Rev. Henry Moule said the evils of pollution and waste were the necessary results of the daily accumulation of putrefying and putrefied matter in drains, sewers, and cesspools; and to deal with such intractable substances *en masse* was impossible. This serious evil must be traced and dealt with in detail, which by the water system was impracticable. A general system, however, of earth-closets was perfectly feasible, and to such an extent that the cleansing of towns and villages would in many cases be not a matter of expense, but of positive gain. By this system that substance was removed from the drains and sewers which was most offensive, and which presented the greatest difficulty to deal with; and thus the necessity of flushing was avoided, which reduced the quantity of water required by five-sixths. The remaining sixth could be dealt with quite easily, especially if slops were removed from the sink-water, which could be carried off by small drains. The contents of the vaults need not be carried away oftener than once in three months, and if the product were only worth 10s. per ton, it would, from a town of 25,000 inhabitants, produce a revenue of £10,000 per annum. The Rev. gentleman further proceeded to narrate the financial results which might be obtained by the application of sewage to garden ground, and the general effects produced by the use of the earth-closet system, the details of which may be found in his printed communication.

Prof. Wanklyn wished to say a word with reference to the question of standards. The first speaker had stated that .003 of a part per cent. of organic nitrogen was sufficient to condemn an effluent, and moreover that chemists were perfectly able to determine that amount. Now he wished to state that there was no process known to chemists by which the organic nitrogen could be determined. There was one process which he believed was only employed by one chemist of eminence, and it yielded an error of 1,000 per cent. on the substance on which it was applied, which was perfectly absurd. Thus if the water yielded an impurity of .5, the experimental error was 50 or 1,000 per cent. There were, however, indirect means of ascertaining what would be implied by three parts of organic nitrogen per 100,000 parts of water, or .003 per cent., and it would no doubt surprise some gentlemen to be informed that such a standard would admit the foulest sewage in the country into any river, and thus any legislation which would enact such a standard would license the passage of the filthiest impurities into our streams. He was not in favor of what were called chemical standards, to be applied to effluents, and the only one he would be inclined to adopt would be transparency. He agreed with General Scott that the only practical enactment would be to insure that a perfectly clear liquid should flow into the rivers.

Mr. Baldwin Latham, speaking as an engineer, thought it very desirable to separate sewage matters from ordinary rainfall, but it was sometimes a question of very great difficulty when you came to apply it. For instance, he might take as a typical town one of those in the Potteries which had been sewered on the separate plan. If the rainfalls were excluded, what with the nature of the materials used in macadamizing the roads, the amount of filth that accumulated upon them with the constant practice of the lower classes of the population of going to the street door and throwing out the whole of their slops on to the highway, all tended very materially with the small rainfall to produce a liquid quite equal in polluting effect to the strongest sewage you could deal with. On that ground, although this arrangement had been adopted in two such towns by the Duke of Sutherland—who had come forward as the largest landed proprietor of the neighborhood to assist them in getting out of their difficulties with regard to this question, thus setting a good example to other land-owners—it had been found absolutely necessary to make a connection between the rainfall sewers and the sewers proper, so that when there was a small amount of rainfall passing through the sewers a connection might be made between one series and the other, and the small amount of rainfall might pass into the sewage proper; whereas when the flow increased and the volume of water was larger, the whole of that water would pass away to the natural streams of the district. There were, however, many districts more happily situated, such as those governed by rural sanitary boards, who had nothing to do with the drainage of the roads or the making of gulleys, and who could therefore carry out their works much more cheaply than had been done by authorities acting under the jurisdiction of local boards. This question of the separation of fæcal matters from rainfall to a certain extent opened out the question, what was the best system to be adopted for the collection of fæcal matters, whether they were to be passed into the sewers or dealt with in any other way? As a general rule, he thought, in large towns, where there was an abundance of water, the water-closet system would always commend itself for adoption, because, from long experience on this question, it had been shown by the River Pollution Commissioners that from the inquiries they had made the amount of polluting matter contributed by water-closets was not materially in excess of that where the ordinary middenstead or dry system was in use. They also knew that in some towns which had been put under the system of collecting fæcal matter directly from houses, the amount collected did not equal more than one-tenth of the whole produced, so that nine-tenths must find its way ultimately into the sewers. There was also this advantage, that where you had water brought into towns for various purposes, it could be made use of for carrying away this matter immediately from the premises, for that was the important point in a sanitary point of view; and no dry system whatever had been introduced which did not render it necessary for it to be kept about for some time. He was not going to say there was no value in the earth-closet system, for he had himself recommended sanitary authorities to adopt it, and thought it a very valuable appliance in some positions. Capt. Liernur's system also had much to commend it, and it was certainly far preferable to that horrid system of pails which was now adopted in many manufacturing towns in Lancashire; to carry such disgusting matter through the habitations of the people was an abomination; the very sight of the process was disgusting to any one, more especially if the removal was neglected for a short time. The positive abomination of the apparatus was such, and the interval for collection was so great, that an accidental visitor to an establishment quite put out the ordinary calculation, and rendered what might be otherwise a little unpleasant, an intolerable nuisance. Captain Liernur's system had this advantage, that it collected the whole of the fæcal matter, but did not depend on manual labor. It did not invade the privacy of the dwelling, being effected by special pumping machinery, and consequently the work could be performed much more cheaply. With regard to the sewage of Manchester, he believed the analysis of it, taking it with all its fæcal matter kept out of it, was more foul than that of many water-closet towns. He knew that towns had many deficiencies to contend with, but he believed the separation of fæcal matter from rainfall was of great importance, and should be insisted upon in almost every instance.

Mr. Charles James Wahab, referring to the North Esk, a small river in Midlothian, said there were nine paper mills, containing sixteen paper machines, situated upon it, and consequently a very large amount of polluted water was discharged into the river. The stream was small, only containing below the paper mills 3,500 cubic feet a minute in the summer, or 31½ million gallons in a day. The impurity was equal to 14.5 grains per gallon, or a total equal to 29 tons 2 cwt. daily. Above the mills this stream contained an impurity of 7.6 per gallon, which, upon the same quantity of water, would amount to 15 tons 5 cwt., so that the added impurity in passing the mills amounted to 13 tons 13 cwt. It had been found, however, by numerous carefully conducted experiments, that only 6.4 grains per gallon were added from all the paper mills, so that there remained a quantity of 7 tons 13 cwt. from other causes. He had only to add that this stream had upon its banks, besides these paper mills, a number of little villages and gentlemen's houses, and it was his opinion that a great quantity of this impurity, which was unaccounted for, arose from the sewage of these houses and villages. This showed the great importance of treating sewage in a different way to manufacturing refuse. It had always appeared to him extremely hard on manufacturers that they should be obliged to purify their discharges and brought into Court as contaminators of rivers, while riparian proprietors and the agricultural labor of the country were evidently to blame to almost the same extent.

Mr. Charles Elcock thought the object of the meeting should be practical, and that it would do well to take into consideration the question of the propriety of separating all fæcal matter and manufacturing refuse from the rainfall, and, if possible, to decide whether it was desirable or not. It appeared to him it was essential it should be done, if the rivers were to be maintained in that degree of purity which they ought to possess. It was said that the amount of impurity added to rivers from water-closets was very small, and this was brought forward as an argument why excreta of this kind should be allowed to go into them. But if it added anything to the already existing impurities in the sewage proper of a town, it appeared certain such a discharge ought not to be allowed. The next question was as to the most suitable means by which the fæcal matter could be kept out of sewers. There was no doubt that so long as towns existed, sewers must exist, but that fæcal matters should be allowed to go into them no sane man would admit. No one need go further than Over Darwen to see the effect of a little fæcal matter getting into a sewer, for any gentleman who during the last month had walked through the streets and happened inadvertently to get over one of the gratings would have perceived such a stench, as, to use a common expression, must be experienced to be appreciated. What then could be done to get rid of the night-soil instead of passing it into the sewers? They had heard a very elegant term used for the receptacles, as they were called in Manchester, in which they were collected, but wherever the system of collecting the night soil in pails, whether wooden or galvanized, had been introduced, it invariably tended to a decrease in the death rate and in the prevalence of typhoid fever, which was a most important item to take into consideration. He contended under proper arrangements these receptacles were not objectionable, and he had had considerable experience in dealing with them. In fact, there might be a pile of them in the room reaching up to the ceiling, and no one would be aware of it if his eyes were shut. It had not, however, been sufficiently considered that night-soil was not the only thing to be got rid of. There were other nuisances in towns quite as great, though engineers years ago, not having their attention sufficiently directed to the matter, took it into their heads that getting rid of the night-soil was the one thing for them to do, and consequently the water-closet system was invented, than which a more ingenious machinery could not be suggested for the introduction of poison into houses, and Acts of Parliament were brought into force to compel their adoption. Happily in Manchester there was a different state of things, and now no house was allowed to be built which had not in connection with it at least one open dry closet outside the house. It would be found on inquiry that the refuse from houses, streets, abattoirs, and many other places, was quite as injurious as the night-soil nuisance, although it did not make itself so immediately apparent, and this refuse of streets and houses had been found, when properly treated, to furnish the most effectual means of preventing these receptacles becoming in any way objectionable. This was done by simply converting this street and house refuse into the most powerful deodorant known—viz., charcoal—and a means was thus provided for deodorizing the foulest collection from any cesspool, and converting it into a sweet and wholesome mass.

Mr. Alderman Taylor (Rochdale) having heard one or two depreciatory remarks of the pail system, wished to add his testimony to its efficiency, being quite satisfied that in many Yorkshire and Lancashire towns it would be impossible to remove the refuse matter without some such system. Many gentlemen spoke of it, and even wrote about it, who had never seen it in operation, or tested it in any way, and whose statements therefore were obviously of no value. The manufacture of night-soil into manure had been spoken of as desirable; it had been adopted at Rochdale some years, and they would shortly be able to prove, not only that it was desirable, but also profitable. When that was the case he thought it was a very serious matter for all towns to consider, because many of them were short of a good water supply; and it would therefore be very desirable to avoid using water, if not absolutely necessary, for carrying away the refuse fæcal matter, as it was supposed, in the cheapest way. He however believed that that so-called cheapest way was the dearest that could be devised, for you not only spent a large sum in water, but diminished the value of the manure amazingly. He might say also that he was a strong advocate for irrigation, but the difficulty they had in the North was in getting land at anything like a reasonable price. Unfortunately the land-owners tried to put upon them a kind of black mail, and they were obliged to give three or four times its natural value for any land to be used for such purposes.

Mr. Adam Scott desired to correct a possible misconception arising from what Mr. Latham had said with regard to Captain Liernur's system. He seemed to think that that system only effected the removal of fæcal matter, but it also removed the house slops and other matter which was quite as important—viz., the fatty sedimentary deposits from kitchen sinks which were practically of the same nature, though they had not passed through the human body, and therefore were not so far on the road to putrefaction—and the other various organic matters in solution which caused the great difficulty in the sewage question. The muddy detritus which found its way into the street sewers was of a very similar character, but Captain Liernur did not allow any of that mud to collect, as, if time had allowed, he could easily have shown.

THE CHAIRMAN said the question of separating fæcal matter and manufacturing refuse from the rainfall was a most important one, but as there were so many opinions upon it, and so many methods under trial, the meeting would probably agree with him that it was not desirable to pass any resolution upon it. They would therefore pass to the consideration of the third branch of the subject, "Methods of treating water-carried sewage so as to purify it before discharging into rivers."

MR. C. RAWSON said he was naturally a great believer in one process of treating sewage, viz., the A B C, being the managing director of the company, but while advocating the advantages of his own system, he should be sorry to say a word against any other. He contended that in any system of precipitation there were four points which should be carefully attended to: one, that the effluent water should be fit to go into the river; second, that in the treatment of the sewage proper no nuisance whatever should be created; third, that there should be no chemical used which should in any way deteriorate or injure the manurial qualities of the sewage, for when they considered the extreme care with which farmers collected all the manure they got for use upon their fields, it was rather a reflection upon the science of England that at the present moment they were pouring into the rivers and losing by far the most valuable manurial material which could be used; fourth—and this was perhaps the most important in the eyes of many corporations—that the manurial produce should be valuable and should pay the whole expense of treating the sewage. He believed that the A B C process in every way fulfilled these four requirements. He would not stay to explain the process at present, but he had brought forward the evidence of independent officials bearing testimony to its success in the four points he had mentioned. His experience had led him to believe that there was not a single product of any manufacture or dye works which might not flow into the sewer and be treated by the A B C process as easily as the sewage itself, and, in fact, sometimes these constituents actually assisted the precipitation. At Leeds the sewage came down charged with most extraordinary dyes, yet after being treated by the A B C process, the effluent water formed a beautifully clear white cascade from the end of the works, which astonished everybody who saw it.

MR. CHARLES JONES said he had intended to offer a remark or two on the separate system of carriage, but he would only add, with reference to that point, in addition to what had been said by Mr. Latham, that he wished that the Government would give some help on the question, and if any deputation were appointed he hoped they would suggest that the Local Government Board should, when schemes are suggested to them, consider the advisability of recommending the separate system, as they would thereby strengthen the hands of engineers in dealing with local boards. It must be remembered, however, that they had to do, to a great extent, with the water carriage at present in existence. Water-closets were already established to the number of many thousands, and they must be dealt with, and the principle on which they had to work was to get rid of the nuisance at the least possible cost. Therefore, while they had every respect for the A B C, and many other systems, he thought those who had to deal with the question practically must look first to the question of expense. Now, experience showed that lime was the simplest, best, and most efficient means of dealing with the question. He had tried the lime system at Ealing for many years, and it had proved thoroughly successful. This might be gathered from the fact that they were next door to the Conservators of the Thames, who had never attempted to interfere with them. He therefore suggested that this system should be tried by municipalities and other authorities before putting their constituents to the enormous expense required by many systems which were laid before the public. He firmly believed in irrigation, but also advocated the use of lime in conjunction with it, because in thus treating the sewage you got rid of that which was obnoxious, and obtained the compound which was most valuable to the agriculturist. You could then do with a minimum of land for turning the effluent water upon, and the land so used occasioned no nuisance whatever, though it would produce most excellent crops. He thought if they waited until earth closets or any similar system were adopted throughout the country, they would have to wait a long time, and did not believe that any government would urge the adoption of any such scheme. As to the disposal of the sludge produced by the precipitation of sewage by means of lime, various methods had been suggested for disposing of it which he had not time to describe, but would only say it was to be dealt with, and without difficulty. He was now dealing with it at Ealing and in other towns in various ways, and in every town the treatment would depend upon the circumstances of the town and the nature of the soil, whether it were clay or light land.

Mr. A. M. Fowler (Salford) said it seemed to him that the arguments had been all on one side, for not one word had been said in favor of the manufacturers, though it would be a very serious question indeed for them if their interests were not carefully watched. In the case of the River Aire, at Leeds, there were very many large manufactories upon it above the town, and he remembered very well when the question was agitated there, the great mill owners got up a meeting at once, and formed themselves into a deputation to wait upon the Home Secretary. If any stringent or arbitrary measures were put in force to purify this river, no doubt the same course would be pursued, and opposition would be encountered. The question was not whether purification could be accomplished—for there were several methods of doing it—it was simply a question of expense, and therefore, if the A B C process could be worked so economically as had been stated, in a town like Leeds or Manchester, he thought it might be very usefully introduced in towns where they were so situated that land could not be obtained. He had had fish living in this effluent water several weeks by the side of a globe containing water supplied by the town, and strange to say the fish in this latter globe died two days before they did in the effluent water from the sewage. He had not the slightest interest in this process, either directly or indirectly. It so happened that in the neighborhood of Leeds and Manchester, there were two wealthy navigation companies, the Aire and Calder Navigation, and the Bridgewater Canal. The Aire and Calder Navigation Company were the custodians of the river throughout its whole water shed, and would not allow a manufactory or anything else to abstract one drop of water from the river without returning it again. Therefore if a manufacturer took a quantity of water, he could not turn it into the sewers, where it would pass down to the sewage works and be deodorized, but must turn it back into the river, so that the river by such an operation became fouler than before. As Sir Joseph Heron had said with regard to the Irwell, it was worse above the town than it was below it, because the manufacturers turned their refuse into the stream.

Mr. W. C. Sillar feared that the unanimity with which the meeting had received the first proposition as to the evils existing, and the necessity for a remedy, would not be found when they discussed the processes which ought to be adopted, nor did he think a room of that kind was the place where the owners of any particular process should advocate their ideas. The real judges of this matter were the town council, or sanitary authorities, in whose hands was vested the solution of this problem. In days gone by it was said that the problem was very difficult, because there was no known process by which you could get out of the difficulty. Now, on the other hand, they were told that so far from there being no process, there were so many that positively they could not make up their minds which to choose. He was much interested in one process, but at the same time, if a better one could be shown, he should be the last to lament it. His object was to see the rivers clear, and the wealth utilized which now was wasted. One of the great difficulties they had had to contend against was the apathy of town councils. A great deal was said about the expense of this process and of that, but they never calculated the expense of not doing it. It was as in the case of railway accidents, they never could get directors to avoid them until the damages given by juries brought them to reason;

and if a calculation were made of the sickness and death which arose from polluted water, the responsibility would be so heavy that public opinion would be brought to bear, and municipalities would be compelled to adopt some process or other to prevent pollution. A good deal had been said as to the advisability of separating refuse and fæcal matter from sewage, but as he viewed it the problem was given—sewage containing this matter, how was it to be treated? There were plenty of processes, and he trusted some legislation would soon be initiated by which the matter would no longer be allowed to rest in abeyance. Some of his friends had been willing to bear the whole expense, if towns would only allow their sewage to be treated so as to demonstrate the practicability of the process. This was not a question in which personal interest should be allowed to come into play; there ought to be some impartial tribunal appointed to say what ought to be done.

Mr. Alfred Smee, F. R. S., said he came to the meeting to learn and not to teach, but in consequence of some amount of misunderstanding which appeared to exist as to his views, and from what Mr. Hope had said, he felt bound to say a few words. He agreed with him that sewage must ultimately be cleansed in the earth, and that they never could get water which once had been sewage fit to again go into a stream without filtration through the ground. Many experimenters stated that they so purified the water that they could recommend it to be drunk, but there was no town in England where the inhabitants pumped back their sewage after they had purified it into their own water tanks. Only the other day, when at the Wallington Station, he asked what the state of the water was, when he was informed it was quite unfit to drink, that it had filtered through from the sewage irrigation ground. Although that was badly done, he believed that sewage might, after precipitation, be so cleansed by passing through or over the earth that it should be perfectly fit to again enter the river. But how was it done? It was put on the grass, where it destroyed the roots, and the engineers said that this grass was the best cleanser. Undoubtedly, because it was in precisely the same position as a scrubbing brush would be, every blade of grass being covered with water, and every blade wrapped round with fæcal matters, and this was given to the cows. The same thing continued when sewage grass was dried and made into hay, and if any one would take hay made from sewage grounds and rub it, he would find the nauseous, filthy matter encased upon it. As an impartial observer, and from experiments made at his own experimental gardens, he was able to say that sewage produce did prematurely decay, and he did not believe it was right to cut grass when covered with fæcal matter and give it to cows; common sense dictated that such grass was unfit food for cattle, though no doubt cows had a liking for foul food to such an extent that the man who valued his milk in India kept his cows carefully tied up, in order that they should not eat human ordure. With regard to the question whether sewage grass affected the milk, he had published experiments of his own to show that it did. A most elaborate set of experiments had been conducted at his farm yard, every day in the year, and they found it very difficult to make butter from sewage milk. Sometimes a change took place in the constituents of the milk, and the caseine would sometimes dialyze from milk produced in this way, showing that serious changes occurred in the animal economy, if cows were fed on excrementitious and not on pure grass. Some people might not care for the cows, but he, as a medical man, must care for human beings, and when he stated not only that grass was being used as a cleanser for sewage, but that water-cresses which were sent to London and consumed by the aristocracy, were used for this purpose, he thought it time to speak, and say that vegetable matters were not proper things to use as scrubbing brushes to remove the solid matter from sewage, though the earth itself might be employed with advantage.

The Rev. J. C. Clutterbuck said he wished to speak on the last branch of the subject, as to the evils arising from the non-separation of the rainfall from the sewage proper, these evils having come much under his own observation. This matter certainly appeared to him to assume most gigantic proportions, with reference to London, which was situated on a tidal river, and owing to the flux and reflux of the tide this fæcal matter, as well as a great portion of the sewer water of the street, was stirred up by every tide, and oscillated backward and forward in the Thames in a way which few people would believe. He had also tried certain experiments with regard to the A B C process, the conclusion to which he came being that the difficulties of precipitation were so great that it would be almost impossible for it to be applied generally. He had had opportunities of seeing many places where sewage had been dealt with, and had come to the conclusion that it was only by its application to the surface, and filtration through the substance of the soil, that, as far as our present knowledge went, purification could be accomplished. He believed it had been so accomplished by Mr. Hope, and it was likely to be so by Mr. Bailey Denton, at Merthyr Tydvil, though he hoped that gentleman would not restrict too much the area to which he applied the sewage.

Mr. Edward Hall said there seemed to be some danger of forgetting that this sewage question was simply a branch of the grand question of the removal of all kinds of refuse, and it would be impossible to obtain the purification of sewage, whether removed by one process or another, unless street sweeping was attended to much better than it was in any town in this country. In Paris, during the time of the Empire, street sweeping was thoroughly attended to, and to that, and also to the peculiarity of the Parisian system as regarded house refuse, he attributed the comparatively low state of mortality there. He had made a careful comparison of the mortality of Paris and London, a matter by no means easy, because the census returns in France were made only once in five years, and he found that the mortality of Paris was very slightly above that of London, a proverbially healthy metropolis. The Paris system was to deposit the house refuse in the streets, and an admirable system of street cleansing being also adopted, he contended that it would be far better in London to follow the same system, and to remove it by an improved system of street cleansing, rather than to hoard it as was practically done in and about our houses, for by such a method not only would the rate of mortality be diminished, but the solution of the sewage question would be rendered much more easy. One great difficulty was to keep out of the sewers that mass of filth which was deposited in the streets, not ordinarily called house refuse. But if there were a proper system of street cleansing, a great deal of what now passed into the sewers would be removed by horse and cart.

Mr. Henry Morgan (Lodge Farm, Barking) said he was glad to hear Mr. Smee take exception to the evils which occurred on some sewage farms, though he was sorry he did not go on to say that he found none such on the large farm at Barking, where for eight years they had dealt with the North London sewage. They had there carried out experiments for the purpose of throwing down solid matter held in suspension by the Phosphate Sewage Company's process, and pouring the effluent water on to the farm, the result being that they grew such crops as attracted Mr. Smee's attention and approbation, and he might remind Mr Smee that they had had the pleasure of supplying him on two separate occasions with mangold-wurzel grown by sewage for the use of his own cows. Of course, if such practices as he had referred to were general, there would be an end of irrigation, but he hoped the meeting would remember that when they spoke of "purity" being obtained by passing sewage over dry land, or through it, or both, that the exact meaning of the word was rather debatable. He doubted very much whether the word "potable" was applicable even to the water which had passed through the land and been applied to growing crops; that was a point, however, which chemists alone could decide. With regard to the scheme which had been referred to by Mr. Hope, as laid before the Select Committee for the purpose of dealing with the North London sewage, as he represented the company which took that concession from Mr. Hope, he was bound to say that whatever the Select Committee might have thought of the scheme from the evidence then before it, he would undertake to bring evidence now which would show that it could not have been carried out successfully by private enterprise.

Mr. BAILEY DENTON wished to point out a little inconsistency in the remarks of Mr. Alfred Smee. He commenced by speaking of the great advantage of filtering sewage through soil, and in fact admitted that the difficulty could be overcome by that process, and then he spoke of the roots being so covered with sewage matter that they were repulsive in character. What Mr. Smee stated was an utter impossibility, because, if the sewage passed through the soil as well as over the surface, it was perfectly impossible that the sewage matter could cling to the roots of the grass.

THE CHAIRMAN thought the meeting would agree with him, that the Council of the Society of Arts were perfectly justified in calling together this Conference, since they had heard persons from all parts of Great Britain, though they had not heard any gentleman from Ireland who could speak as to the state of the river Liffey. Possibly the case of Ireland did not present the same urgency as other parts of Great Britain, because there were not so many manufactories there. He was glad to notice that several suggestions had been made; one, no doubt, from a very good motive, from General Scott, to the effect that if they legislated too rapidly, they might injure their cause, and that they should first ask the Government to insist on the solid matter being taken out of sewage and the liquid only allowed to run into the streams. He did not think his friend General Scott had had so much experience of Lancashire and Yorkshire streams as Sir Joseph Heron and himself had long had, because if some of the coloring matters now turned into these streams were allowed to remain, their condition would be perfectly insufferable. They had all seen or heard of Gainsborough's "Blue Boy," but if they went to some of those streams in which indigo and Prussian blue was running down, they might see fifty blue boys come out; and if they went to a stream in the neighborhood of which black dye was used they might see fifty boys go in, and fifty "men and brothers" come out in a state far worse than that in which they went into the stream for the purposes of ablution. It was therefore quite as necessary to get rid of the soluble matters as of the solids, especially in fishing streams, for one of the most poisonous substances, and one of the most common which destroyed trout and salmon more than any other, was oil of vitriol. This could be removed as easily as possible by simply filtering it through lime-stone, and why should that be allowed to go into a stream simply because it was soluble? No doubt it would much improve the system of sewage if all soluble matters were taken out, but that was not sufficient. The meeting seemed to agree that the rivers were intended for the use of the whole community who inhabited the drainage area through which the rivers flowed, for the various purposes for which rivers were useful to mankind, and that no one town in that area had a right to appropriate that river and destroy its usefulness to other communities; similarly, that no one manufacturer had a right to say, I add to the production of the country, and therefore I will take the river, which is intended for the benefit of the whole district, and destroy its usefulness before it comes down to others. Each river therefore ought to be preserved in such a state of purity—absolute purity they could not obtain—that it might be of use and benefit to the whole drainage area which it watered. What then was the stage at which they had arrived? They would remember *Punch's* cartoon of last week, referring to a picture of Millais, where Mr. Disraeli said, with reference to the Arctic expedition, "It is possible; therefore it shall be done." By the first resolution it had been asserted that the purification of rivers was possible, and therefore it should be done. It was not for them, out of so many competing schemes, many of which were excellent, to select one and say it should be applied, but as a chemist he might be allowed to say that he had looked at all the different kinds of impurities which passed into the rivers, he had seen the different methods which had been used for removing them, and there was no one class of impurities which could not be removed, generally with great profit to the manufacturer. They must not attempt to do this in an arbitrary way, but must allow manufacturers to understand that the country intended to have its rivers pure. They would not say to any man, you shall do this or that, without full time for consideration to apply the remedies, but that it was the intention of the public and of the legislature to purify the foul rivers of the country, and, as Mr. Thom had showed, he believed the manufacturers would then come to the legislature and ask for further restrictions. This had been their experience with the alkali works. A few years ago they used to foul the air most abominably with muriatic acid gas, and cried out very much against being forbidden to do so, but they had now found that they could not only prevent this easily, but that they could do so with profit, and they actually came to Parliament and said—"Be more severe." So he believed it would be with manufacturers generally with regard to the fouling of streams; it would be for their benefit as well as for that of the community at large. He believed, therefore, the practical result of the Conference would be that they ought to tell Mr. Disraeli that the thing was possible and that it should be done. If that were done, he believed a solution of the question was not very far from accomplishment, and that they would soon see their beautiful rivers restored to that bright and clear color which they ought to be, instead of being, as they now were, a disgrace to the country through which they passed.

SUEZ CANAL TONNAGE.

From the "Nautical Magazine."

In making any dock, or harbor, or canal, or any approach to it from the sea, the undertakers of the work have to provide for the maximum size of ships likely to use it.

The three points they have to consider are: (1) of what width are the ships for which they have to provide; for unless the dock-gates, and the channels, and the canal are wide enough, it will be of no use when completed. But width is not the only question. They have also to consider and provide for (2) *the length* of ships. A short, wide ship will be able to navigate in a channel, or in a dock, which would be wholly inaccessible by long, narrow ships; and thus it happens, that in order to provide for long ships, locks must be of great length, basins must be of great area, and the bends and turnings in channels and canals must be carefully and expensively made, so as to avoid anything like sharp curves; but, still further, length and breadth are not the only elements, for there is a third element—viz. (3), depth of ships. It will be useless to provide a broad and well-arranged channel without regard to its depth, or to construct broad and long locks, or docks, or canals, without regard to their depth, for large ships must be deep ships. Therefore, sufficient depth has to be provided; and to provide depth is one of the most expensive parts of the construction or arrangement of the undertaking.

A dock or canal company having been at the expense of providing adequate length, breadth, and depth, for the accommodation of ships, must necessarily be most equitably remunerated for their outlay, by levying dues on ships on a system founded on their length, breadth, and depth. It is absurd for the shipowner to say to a dock or canal owner, "It is true I occupy so much space in your undertaking; it is true my ship requires so much length, and so much breadth, and so much depth, and you have provided them, but although I occupy that space, and could not get through unless you provide it, still as half my ship is for my own purposes occupied one way, and the other half occupied the other way, I ought only to pay as if my ship were half her actual size." But this is exactly in effect what is urged. On the other hand, we must notice that dock owners are very unfair to steamship owners, when they charge as much for a steamship occupying space for a day or two as they do for sailing ships occupying space for several weeks.

The gross tonnage alone, being founded as it is on the actual cubature of the internal contents of a ship, is the only tonnage that takes into account the three elements of length, breadth, and depth, and for such an undertaking as the Suez Canal, where time is no element in the charge, or for an international ton, it is the best, because it is the only accurate gauge of the description of the ship.

And even for charging light dues, the gross tonnage is the correct standard, for the following reason: The payment is made for services rendered. In the case of the steamship *Asia*, formerly of the Cunard Line, when she had on board machinery worth say £50,000, she paid on the register tonnage of say 1,200 tons. She grew old, the engines were taken out, and she was converted into a sailing ship, and was, as a fact, about half her former value, and had to pay dues on the whole tonnage of the hull, or 2,000 tons, or thereabouts. Register tonnage has been adhered to by steamship owners, because dock owners do not allow time as an element of charging dues, and the steamship owner looks upon the advantage he gets by paying dues on the register tonnage as a sort of rough and ready compensation for his frequent visits; but admits universally that if time were taken into account, gross tonnage is the proper tonnage on which to levy dues. And again, as between ship and ship, the gross tonnage is the proper system, because (1) it is the only system founded on the cubature of the hull, and (2) because it is free from any of those disturbing causes arising from deductions for engine-room, and (3)because it leaves the ship owner free to arrange the internal part of his ship as he pleases, instead of having to arrange it (in a way that is fair to nobody) for the purpose of getting a small register tonnage.

The above are some of the reasons in favor of gross tonnage as the basis of taxation for the Suez Canal and of an international ton.

Our present net register ton is unjust in the extreme in the case of steamships, both as between steamship and steamship, and as between sailing ship and steamship; and, further, it is monstrously unjust to the shareholders of the canal, and as between nation and nation. No one knows this better than M. de Lesseps. This subject is exhaustively discussed in our number for February, 1871. We, therefore, refer our readers to that article, merely mentioning that it was deemed to be of sufficient importance and accuracy to be reprinted by the Board of Trade.

The system in use in the Danube is a fairly good system for that river; but we must recollect that it was only adopted failing the adoption of the gross ton. And we must further bear in mind that, although we have only few positive arrangements internationally as regards the register ton, the gross ton is as a fact almost already an international ton; for the gross tonnage, according to our system, is stated on the papers of ships of the following countries: Austro-Hungary, France, Italy, Denmark, Germany, United States; and it is from the gross tonnage so stated, that in many cases, and by various ways, the register ton, or chargeable ton, is arrived at after deduction in foreign ports.

Other systems have been proposed: (1.) A fixed deduction; but a fixed percentage, made applicable to all ships, whatever their trade, would be unjust, as it would operate unequally between ship and ship, and because, to meet extreme cases, it would have to be very large. To take an actual case, it would be absurd to say that, because the *Republic*, in making a voyage to the coast of South America, would require say 40 per cent. deduction, another ship, or the same ship, going to New York or to Oporto, should have the same deduction. She would, in fact, in the latter case, have a deduction for space in which it would be well known that she ought to carry cargo. In one case there would not be deduction enough, and, in the other, cargo would be carried in the deducted space; or, if not, what is worse, it must remain idle, or be filled with a dead weight of coals that are not wanted. How these arguments apply at all against gross tonnage, pure and simple, it is difficult to see.

Another proposal we have seen is that, having fixed the gross tonnage, there should be deduced therefrom a register tonnage that shall be less than the gross tonnage, according to the nature of the service of the ship; that is to say, a long-voyage ship should have 30 per cent. deducted; a short, foreign-going voyage ship, 20 per cent., and a coaster 10 per cent.

This would have involved the following awkwardnesses:

(1.) An addition of about 20 per cent. to the dues paid by all home trade coasting steamships. In some cases, 40 per cent.

(2.) An addition of about 13 per cent., in some cases more, to the dues paid by short-voyage foreign-going steamships.

(3.) An addition of 3 or 4 per cent. to the dues paid by all other steamships.

(4.) The alteration of the official register tonnage where a steamship is laid on for fresh voyages.

Seeing then that by such a system whatever tonnage is to be adopted is to be deduced, and is to be a fixed proportion of the gross tonnage for each class of ship, it will be much better to adopt the tonnage (gross) at once, and then, if necessary, to make a reduction of 10, 20, 30, or 40 per cent. in the rate of dues. Ship owners have, however, in the case of the Suez Canal a right to demand that the charge shall be made on the nett register tonnage, for Mons. de Lesseps pledged his word that it should be so charged, and, on the faith of his word, they have specially constructed ships for the Canal.

It was argued against gross tonnage for the Suez Canal, that it would be unjust between three classes of ships: A, high-power, passenger; B, cargo, full power; C, auxiliary; but by charging on the register ton we should be practically shutting out auxiliary screws, and favoring the high-class freight-earning mail steamer; whereas a charge on gross tonnage, which leaves the owner free to use his space as he likes, is a charge on the whole venture, and not on the least valuable part of it.

One very important fact is, that by charging on the gross tonnage every owner is at liberty to vary the internal arrangements of the ship as trade requires, while by charging on the present register tonnage, the full-powered monopolist's steamer obtains an immense advantage, and is able to carry passengers, which, as freight, are, in some cases, the best paying of all cargoes.

As a ton for the Suez Canal, we think we must say, failing the gross tonnage, the Danube rules for nett tonnage now proposed are the best rules. They are, at any rate, better than a fixed proportion of the gross tonnage for many reasons, but especially for the reason that they will lead to the construction of large and light cool engine-rooms, and save the country a good deal of expense in connection with sending home invalided engineers and stokers. A fixed percentage once allowed for machinery would lead to the direct contrary, and would be very damaging to the personnel of the Mercantile Marine; and they are better than a sliding scale of percentages, which is satisfactory to no one but the ship owner who, by a juggle in constructing his ship, is able to shift the charges on to some one else.

The Paris Academy lately received, from a dyer at Puteaux, a note, which was listened to with manifest incredulity. It referred to a fire produced, the note said, by the electricity liberated when certain stuffs are rubbed in a bath of benzine for removal of greasy matter. On further inquiry, however, the phenomenon was ascertained to be real. The case was thus: A workman was charged to take the grease out of a piece of cashmere by washing in a benzine bath; he at once plunged 6 metres of the stuff into the bath, rubbed it vigorously, then hung it to dry, on a peg above the bath. Now, he had often remarked before (and called the attention of others to it), that when the cloth was brought out of the bath and doubled on itself, a strong crackling took place, accompanied with light and sensible pricklings in the hands and the body. In the present case the bath was suddenly inflamed, and the workman was burnt on his arms and hands. This inflammation was naturally attributed to the electricity. This new phenomenon is of some interest, considering the frequent employment of such processes as the one in question; and it may be hoped that the committee which was appointed will throw some light on it.—*English Mechanic.*

The Geographical Society of Paris recently appointed a Commission to draw up instructions to masters of vessels as to the study of the physical geography of the sea. These are now published, and are sent gratuitously to all who care to take up the subject.

THE PRINCIPLES OF DRAWING, GEOMETRY, AND COLOR, AS TAUGHT AMONG THE HINDOOS.*

From "The Builder."

Geometry has been cultivated for many centuries in India, both among Hindoos and Mahommedans as a branch of science as well as a necessary element of education. The theory as well as the practice has been thoroughly understood by the educated natives, and the principles upon which it has been taught, not so much in schools as in the domestic circle, prove that geometry has had an importance assigned to it in former times by enlightened minds who foresaw that it might be made the means of improving the taste and diverting it to the study of simple and beautiful forms. The mode of teaching geometry to children is very simple and impressive, and the materials employed are of the cheapest. A Hindoo child is first taught to draw with the points of the fingers on the floor covered with sand to the thickness of half an inch. The surface of the sand is made level with a straight piece of wood or a piece of split bamboo. Dots or depressions are first made in the sand with the points of the fingers held at certain distances, the thumb, fore, and little fingers being generally employed as the compasses. At first the eye is accustomed to judge of distances by the position of dots—the next step is to connect these dots by straight lines—then to draw straight lines regularly between the dot—then to prolong these lines till they meet beyond the dots. Square forms are usually selected as being the easiest for a child to draw, and more attention is bestowed on educating and accustoming the eye to judge of distances than in drawing perfectly straight lines. At first plain squares are drawn preserving the dots; then various combinations of the square, vertically, horizontally or diagonally arranged. This is, perhaps, the most impressive way of teaching the various uses and combinations of the square, and of educating the eye to judge of its relative size and value for filling given spaces, as it can be seen at a glance, and without much effort on the part of the child, which squares are large and which small. The multiplicity and variety of these patterns in which the square forms the basis are very instructive. This system of instruction has the advantage of explaining itself, without being perplexing or intricate, and of accustoming the child to draw lines in a bold, free way from the shoulder and not from the wrist, as in our systems of drawing. The patterns are usually drawn at first from 18 in. to 2 ft. in length, so that each square would vary from 2 in. to 4 in. After a facility of drawing them with single lines has been acquired, they are done on a larger scale with double lines with the fore and little fingers. Curved lines are then added to complete the border of the pattern. The square is looked upon by the Hindoos as the most important geometrical form, and the basis upon which the measurements of their designs and patterns are to be laid down. These illustrations may have a special interest, as they were drawn by the Hindoos themselves, and many of them had been in use in families from whom they were purchased as the ordinary patterns in daily use in Hindoo families. They hardly deserve the name of drawing lessons, as there is both a religious and a caste importance attached to them, for the different trades and occupations of the Hindoos are indicated by the patterns which are drawn in white on the road in front of the houses. In some families there are as many as 1,200 patterns in use, and it is occasionally the boast of the women who draw them, that they can go on for three years giving a new pattern every day. The name given to this kind of pattern in Southern India is Mogoo, and when girls are about to be married, one of the tests of her domestic education is the number of these patterns which she can draw. There is some sense in this, for it is an index of the care that has been bestowed on her domestic education, and a proof to her neighbors that she has been taught to clean the house, and to say her morning prayers to her preserving or her

* A paper read before the Edinburgh Architectural Association by Alexander Hunter, M. D.

destroying deity. Among the Buddhists and the early Hindoos the square was supposed to be typical of the solidity of the earth; the triangle, of fire; the circle, of the sea or water; and the crescent, of air. To these the later Buddhists added a fifth element, or the winds, represented in some instances by a pyramid with turn-up points, as seen in many of the pagodas of Burmah and China, and in a few of India. But to return to the square and its uses as applicable to ornamental purposes. The Hindoo child is taught to examine and to reproduce for itself, and to attach some meaning to each; for instance, in several of these patterns we see a central square, with numerous others arranged about it in pleasing combinations, each square touching the next, but the idea of solidity or continuity destroyed, and an approach to decoration given, by the mere arrangement of a few straight lines within squares. You will have no difficulty in detecting that the ideas for some of these patterns have been suggested by bamboo mats, others by grass mats, and a few by cloth weaving. After a facility of drawing in sand square forms and patterns of simple combinations of straight lines has been acquired, the child is taught to draw them on the cleanly-washed mud floor or on the stone steps at the door; but the style of drawing differs materially from the methods followed in Europe. A little chalk or chunam in fine powder is held in half a cocoanut-shell, and the points of the fingers are dipped into it. A succession of dots is laid down to mark the leading parts of the pattern, the lines of which are drawn by sprinkling the powdered chalk, and not by drawing with a point as we do. In this way a steady hand and a bold freedom of style are acquired, which are frequently carried to great perfection in after life by both Hindoo men and women when designing patterns for weaving. In order to make the patterns more attractive to children, various simple but cheap and tasteful modes of combining colors with the drawing and geometry are had recourse to. One of the most common methods is to fill up the squares or spaces with colored powders, and either to trim up the lines of junction with a split and pointed bamboo, or to pull some flowers to pieces, and to arrange the petals along the sides of the squares, so as to hide the inequalities; for this purpose the flowers of the white jessamine are most frequently selected; sometimes the yellow jessamine is used. The colored powders used for filling up the spaces are natural ochres for the reds, yellows, browns, and purples, mixed with chunam to give brightness. When the following colors are used—tumeric, king's yellow, orange and yellow, chromates of lead, or red lead—the materials with which they are mixed are arrowroot or starch. When delicate blues or lakes are employed, the material with which they are mixed is kaolin or porcelain earth. The object of using these different substances with particular colors is to avoid the chemical action of the lime on some of the colors when applied to a wet floor. This shows a considerable knowledge of chemistry. It will also be remarked that the colors are at first used in their purity, and the chalk, kaolin, or starch is added to brighten the effect. In this simple but ingenious way great numbers of patterns are produced. The use of secondary colors, as green, purple, and orange, is taught by simply washing the floor after it has been colored with the three primaries—red, blue, and yellow. The effects of the tertiary color—russet, in which the red predominates; olive, in which the blue; and citron, in which the yellow is in excess of the other two—are often very beautiful when these are interspersed with other colors. On looking over a number of patterns, it will be remarked that blue is used very sparingly, and always of a very tender shade, and that its place is often supplied by a grey; that white and black are chiefly employed in thin lines or partitions between colors, and seldom as principal masses. It may not be out of place to remark that the effects produced by these colors, flowers and green leaves on the mud floor are far brighter than can be produced in an illustration. It is customary to wet the floor with rice water before sprinkling the colors. As yet the natives of India have seen very little of the fine arts beyond a few busts, and statues, and bronzes of our Indian celebrities, and these not always by our best artists. The works of Chantrey, Foley, and Weeks have riveted their attention; but there are others of our townsmen, as Brodie, Lawson, Clark Stanton, Webster, and the two Stephensons, who are rising, or have already risen, to eminence. Let us try to put some of the best works of these and such like artists before the Hindoos, and if we assist their own modellers and sculptors to produce similar works of their own countrymen, we shall be doing a service to India by helping them to throw aside some of their prejudices of caste, and their more degrading sculptural obscenities. Art in India was far grander and purer 2,000 years ago, or during the early Buddhist period, and there are sculptures still in fine preservation, from having been carved in granite, that show proofs of a careful study of chaste and simple nature. In order to make art telling in India, we must teach them to make it profitable, and if possible cheap, for there are but few patrons of real art in India.

THE PASSIVITY OF IRON.

From "Iron."

To produce in a certain manner the somewhat capricious phenomena of passivity, says M. de Regnon, I use iron wires or rods of fencing-foil, the surface of which is protected, for a certain length, by a glass tube or a layer of mastic. The free extremity, with a length of 2 to 3 centimetres, is plunged entirely in the acid.

I. An electric current *entering* by the iron into nitric acid, renders the iron passive while the current lasts; and after rupture of the current the iron remains passive. A current *leaving* by the iron destroys the passivity, and this change of state may be reproduced indefinitely. Iron acting as positive electrode in a mixture of sulphuric acid and water, liberates oxygen, is weakly attacked, and becomes passive for nitric acid. A reversal of the current's direction destroys the passivity.

II. One may *stop* the attack of iron by nitric acid, by touching or (better) rubbing it in the nitric acid with a body that is a good conductor and not attacked by the acid, such as platinum or conducting charcoal. This action of charcoal explains why steel and cast iron become passive of themselves. The experiment succeeds better the larger the surface of contact, and the larger the total surface of the body which is not attacked. Further, the more concentrated the acid, the more easily is the passivity obtained.

III. The contact of a metal attacked by acid destroys, it is known, the passivity. If, then, we put in contact a passive iron wire and an active wire, the final effect will be either the attack or the passivity of both wires. We may unite in a single experiment these two contrary results; immerse the extremity of a piece of foil (the whole surface of which is exposed) in nitric acid to a length of 2 or 3 centimetres. After a short attack, the part immersed becomes passive, and is covered with a dark deposit containing carbon. This done, if we suddenly immerse the foil to a fresh length of 3 or 4 centimetres, the attack commences from above, is propagated to the lower part, and, when the passivity is anew produced, we find the whole of the immersed length charged with black deposit. In this first case the active portion destroys the passivity of the extremity. If, on the other hand, we immerse the foil slowly in the acid, it will remain passive without the part newly immersed undergoing the least attack, as is evident from its clear and bright look. Here the passive extremity communicates its state to the other portion.

IV. We may bathe the end of a wire in water, without destroying the passivity, provided care is taken not to immerse the wire in the water beyond the protective mastic. We may even scrape the wire, in the water, with another passive wire, or with the end of a clean tube of glass, without its state being changed, and this experiment quite destroys the explanation of passivity by formation of an insoluble deposit.

V. I have tried the action of other liquids after having each time bathed the passive iron in pure water, and I have verified the proposition (already known): Oxidating substances are without action on passive iron. Deoxidating substances destroy the passivity.

VI. We may perceive that the actions of contact are reducible to electric actions by means of the following experiments:

1. Connect together a wire of iron and a wire of platinum terminating in a spiral. Plunge the free end of the iron in the acid, and when the attack has commenced, introduce the spiral of platinum into the same glass, or into another glass containing acid, and put in communication with the first by a bridge of platinum. In an instant the iron becomes passive. The same experiment succeeds on connecting iron with conducting charcoal instead of platinum.

2. On the other hand, connect an iron and a copper wire. Plunge in the acid the free end of the iron, and render it passive by rubbing with platinum or with passive steel. This done, introduce the end of the copper wire into the same glass, or into another glass as above, and immediately the iron is attacked.

3. Plunge into a glass filled with acid, or into two glasses connected by a bridge of platinum, the two extremities of two wires of iron connected exteriorly by a conductor. If we then rub in the liquid one wire only with platinum, both become passive; if we touch one wire with copper, both become active. These experiments are more delicate than the preceding, owing to the electric resistance of the liquid.

VII. The passivity may be destroyed in another manner, which shows the *role* of electricity. Connect the wire of a galvanometer, on one hand, with a spiral of platinum or copper which has been plunged in a conducting liquid that does not destroy the passivity—*e. g.*, a solution of nitrate of potash—and, on the other hand, with a wire of iron protected by mastic as explained. Then close the circuit by introducing the iron into the nitrate; the needle indicates an immediate and permanent current going from the galvanometer to the iron. We obtain the same result (which is easy to foresee), if, after rendering the iron passive, and washing it well with water, we immerse it an instant in a liquid which destroys the passivity; *e. g.*, in a solution of marine salt. But if we close the circuit after having washed the passive iron in water, or in a liquid *without* action on the passivity, we perceive a slight movement of recoil in the needle, indicating a first current of very short duration, going from the iron to the platinum by the galvanometer; then the needle is forced in the contrary direction, and indicates a permanent current from the platinum to the iron. But one finds that, immediately this action is produced, the iron is become active again.

VIII. All these experiments seem to me to legitimize the following conclusions: 1. Most of the causes which produce passivity in iron may be reduced to a voltaic force carrying the oxygen to the iron and polarizing it on the surface of this metal. 2. Most of the causes which destroy the passivity of iron may be reduced, either to a voltaic force of the contrary direction, or to a current due to polarization of the oxygen, and by which it is exhausted; or, lastly, to an absorption of the polarized gas by a body that has avidity for oxygen. I hope shortly to show that these phenomena of passivity are more general than is supposed.

IX. We can now explain two experimental precautions that were insisted on: 1. It is necessary to protect, with an impermeable layer, the portion of wire which is not plunged in the acid, otherwise the acid vapors bring this portion into a state which is opposed to the passivity of the immersed part. 2. When we bathe the passive extremity in water, the metal should not be immersed above the mastic, otherwise the passivity is immediately destroyed, for a circuit is closed by which the polarization is exhausted.

Most of the above experiments were made with nitric acid, marking 35 deg. B.

It appears as the result of some experiments made in Berlin, that while a bar of ordinary bronze was utterly incapable of bearing a strain amounting to 10 tons per square inch, a bar of phosphor-bronze bore this strain applied as tensile 408,230 times before giving way. A second bar of the same phosphor-bronze actually withstood 147,880 applications of a load of 12½ tons to the square inch without fracture.

TECHNICAL EDUCATION.

IN WHAT WAY AND AT WHAT STAGE CAN TECHNICAL INSTRUCTION BE BEST INTRODUCED INTO OUR SYSTEM OF NATIONAL EDUCATION ?*

From "Nature."

It will simplify the consideration of the subject the discussion of which I have been requested to introduce, if we admit frankly that in England at any rate (I am glad to believe that Scotland is more fortunate) we do not possess a system of national education. Such a system, as I conceive it, should afford to all the children of the nation adequate elementary instruction, and, moreover, should offer to all, so far as their capacities and other circumstances will enable them to take advantage of it, full opportunity for further mental cultivation. There are lying before me the calendars of two German schools for boys of the middle class intended for a mercantile or industrial career; the Friedrich-Werder Gewerbe, or Trade School of Berlin, and the Real Schule, under the direction of Dr. Schellen, at Cologne. The courses of each of these institutions following after some preparatory teaching in an elementary school or at home, where reading and writing together with a little arithmetic have been acquired, retain their pupils during nine or ten years; and boys who, according to the reports, were to become mechanical engineers, builders, postmasters, merchants, and chemists, left those schools last July, having attained the ages of seventeen to twenty years. The Real Schule of Cologne, the average number of whose pupils is 580, has 28 masters; the Gewerbe Schule of Berlin, averaging 540, has a staff of 32 masters. In every German town of the least importance there are, in addition to the Gymnasium or Classical School, one or more technical schools resembling those of Berlin and Cologne; the numerous Universities and Polytechnic Institutions furnish the requisite staff of teachers. The fees are small. I have no information as to those of the schools I have quoted, but I find from the prospectus of another very celebrated trade school, that of Barmen in Westphalia, that its school fees for the year are from 3*l.* in the lowest to 6*l.* in the highest class, and that boys whose friends do not reside in the town are boarded for 25*l.* The governments, the municipalities, and private persons vie with each other in placing at the disposal of poor scholars of the elementary schools who have shown superior capacity, the means of continuing their studies in these secondary schools.

I need not describe the elementary schools of Germany and Switzerland; it is now well known that, in them, the children of the poor receive, up to the age of fourteen years, sound elementary instruction, not confined to reading, writing, and arithmetic, but including geography, the outlines of the history of their own and other European countries, a modern language, some elementary teaching in science, and instruction in the religion which their parents acknowledge.

As contrasted with a system of education such as I have referred to and excluding the great public schools, available only to the rich, we have in England for the middle classes schools like those attached to King's and University Colleges, the City of London School, the Bristol Trades School, and, thanks to the Endowed Schools Commissioners, a few efficient or at any rate progressive grammar and endowed schools, among which I would more particularly name the school at Giggleswick, near Skipton, as one where instruction in science has been included in the general plan of instruction, and a small number of exceptional private schools in which a praiseworthy attempt is made to adapt the instruction to the requirements of industrial and commercial classes. These schools, however, rarely retain their pupils beyond the age of fifteen to seventeen years, and when all are reckoned they are utterly inadequate to the wants of the population.

Of elementary school buildings we shall soon have a sufficient number, and it is probable that the duty of the parent to send his child to school will, in some way or other, be in all cases made a legal obligation; but so long as the necessity

*A paper read before the Social Science Association, by Mr. B. Samuelson, M.P.

of rendering our training schools for elementary teachers thoroughly national and efficient is not acknowledged, and so long as the instruction of the children in elementary schools is left in a great measure to the care of other ill-taught children, called pupil-teachers, of from thirteen to seventeen years of age, we cannot hope that our poor will receive proper elementary instruction.

Until the English approach the German schools in number and value it would be vain to expect that technical instruction will be universally accessible, and we can only hope for its gradual introduction, availing ourselves of existing resources, with such improvements as may be looked for under the stimulus of the increasing interest evinced by some of our great corporations, by the parents themselves, and consequently by the Legislature.

One important step in the right direction has lately been taken. Although the political chief is still a species of odd man whose duties include the passing of Ballot Acts, the suppression of foot-and-mouth disease, and the negotiation of Washington Treaties, the Government departments of literary instruction and of Science and Art have been placed under the control of a single permanent administrative head.

I understand technical instruction to include, besides the teaching of industrial manipulation, which for our present purpose we may exclude, firstly, drawing, mathematics, and the physical sciences, which are the bases of the industrial arts; and secondly, the application of those sciences and of the art of design to industrial purposes. I should place in the first division such subjects as:

Pure Mathematics, Chemistry, Physical Geography, Geometry, Physics, Biology, Theoretical Mechanics, Geology, Astronomy, etc.;

and in the second—

Building Construction, Naval Architecture, Applied Mechanics, Machine Construction, Chemical and Manufacturing Technology, Metallurgy, Agriculture, etc.

Although this list is incomplete, it will be obvious that the field is too wide to be covered within the school period, even when the pupils remain at school to the age of adolescence; bearing in mind always that instruction in technical subjects to the exclusion of other branches of a liberal education would defeat its own object. Much more is this the case with children leaving school between the ages of thirteen and sixteen. The choice of subjects must vary with the age at which school instruction is to terminate, and with the future career of the scholar.

A condition precedent, however, to the possibility of technical instruction is a due provision of science teachers. For these we must look, in the main, as to elementary schools, to our training colleges, assisted by such institutions as the Science School of South Kensington, and as to secondary schools, to the Universities, and to institutions like King's College, University College, and Owens College. The training colleges should add a third year to their curriculum; instruction in mathematics and in some of the other subjects which I have included in the first division should be part of the obligatory course; and no elementary school containing, for example, 100 children and upwards should, after a certain date, receive the Parliamentary grant on results, unless it had a teacher who had passed satisfactorily in geometry, in physical geography, and in physics, or in biology. A man thus qualified, having become familiar with the method of science, could, if he chose, afterwards acquire other theoretical subjects as well as those of application, included in the second division—for instance, machine construction, chemical technology, or agriculture—availing himself for that purpose, as to the first class of subjects, of the annual courses for elementary teachers at South Kensington, or of any other means of instruction which may be within his reach. But if he stopped short at the limited but exact instruction in theoretical science which I suppose him to have obtained in the training college, he would be infinitely better qualified as a teacher than if during that course he had taken up a greater range of subjects superficially. Whether he be competent to teach many subjects or not, the children of the elementary schools whom he is to instruct have not time to acquire more than the rudiments of one or two theoretical sciences. At the same time an elementary teacher, who is qualified to give instruction in the applied sciences, will find employment in adult classes, such as those in connection with the Science and Art Department.

Assuming, then, that every elementary school for one hundred pupils and upwards, which would include the principal village schools, had a master or assistant qualified in science, the course of such a school should include, for all the children, linear drawing and lessons on common objects which would be illustrated by locally accessible specimens; the ordinary reading-book should also describe in familiar language the phenomena of nature. Those who are acquainted with the admirable text-books on Elementary Science of Prof. Balfour Stewart, Dr. Roscoe, and others, cannot doubt that the task of compiling such a reading-book will be undertaken by competent hands, as soon as the want of it becomes felt. Indeed, I am not sure that it does not already exist among the publications of the Irish National Board. The older children, those between the ages of ten and thirteen, should receive instruction in physical geography, in the elements of trigonometry, and, from the age of eleven or twelve, in the rudiments of biology or of physics, perhaps, in some exceptional cases, of both. More cannot be done for them in the elementary school; a few should be drafted into the secondary school; but the greater number would at the age of thirteen become full time-workers in the field, at the bench, or in the factory; possessing however, as is now but rarely the case, the elementary instruction required for taking advantage in their leisure hours of the science classes which are to be found in almost every district of the United Kingdom. How much may be done there is evident from the success of the Andersonian University in your city, with its 1,400 students, to whose founder belongs the honor of having been, more than a century ago, the originator of scientific instruction to the working classes. Children thus taught from the commencement by such masters, when they afterwards receive instruction in science, would not be subjected to, and would revolt against, cram like that recorded in the Report of the Science and Art Department for the present year, in which Prof. Ramsay, the examiner in geology, says that "candidates answer one of last year's questions in place of one of this year's, as if they had been specially crammed in last year's examination;" and Prof. Carey Foster, acting with Dr. Tyndall as examiner in acoustics, light and heat, states that a good number of candidates in the advanced stage "suppose that in order to *damp* the vibrations of a string it is needful to *wet* the string," and "that a ship is the kind of vessel that would usually be employed for containing air."

Among other conspicuous examples of adult instruction in science given to the class whose education has been received in elementary schools I may name the lectures for working men of Owens College, numbering more than 600 students, under the gratuitous tuition of the professors of that institution, and those of the Miners' Association of Cornwall and Devon, organized some dozen years ago by Mr. Robert Hunt, F.R.S., Keeper of Mining Records, whose teachers seek out the working miner in his village and make him familiar with the laws of the forces and the properties of the matter with which he is brought into contact in his daily work. But time is wanting to allude further to the subject of adult elementary instruction in science, nor will I enter into the question of science teaching in our great public schools, which has been inquired into by Mr. Norman Lockyer, F. R. S., the secretary of the Royal Commission on Scientific Instruction, whose report will doubtless be forthcoming before long. In secondary schools, assuming the existence of competent teachers, and that they retain their scholars from the age of eight or nine to sixteen or seventeen, I should commence, as in the elementary school, with lessons in drawing and on familiar objects, and in physical geography; and introduce mathematics, beginning with geometry at the age of eleven or twelve, continuing it until the pupil leaves school; systematic instruction in the elements of natural science might begin at the age of ten to eleven with natural history, including geology; and the six years until the pupil leaves at the age of sixteen or seventeen could be made readily to include successively the elements of that science and of physics and chemistry. With the exception perhaps of applied mechanics, it would not in my opinion be possible to include the applied sciences, but the teacher would illustrate his instruction by practical applications. Work in the laboratory is a necessity if a thorough appreciation in kind, however limited in extent, of natural science is to be acquired; but the experience of the Rev. W. Tuckwell, of the College School at Taunton, communicated to the British Association, and of others, shows that a school laboratory need not cost more than 200*l.* to 400*l.*

Only in those cases where school education is continued to the age of eighteen or nineteen years would it be desirable to introduce such subjects as building, or machine construction, or chemical technology. In all other cases more real progress would be made by devoting all the available time to theoretical science. The scholar who enters into active life as an apprentice at the age of sixteen or seventeen, would see in the workshop the application of the principles which he would have learnt at school, and, if diligent, he would find opportunities of further study in adult classes, in factories, and in text-books on special subjects. For instruction in the entire range of theoretical and applied science it would be necessary that the student should continue the course, commenced during the school age, at the University or at a Polytechnic Institution such as there is now some hope that the Science School at South Kensington may become.

Although I have excluded instruction in technical manipulation from the subject of this paper, I think it right to add that the students of King's College and of King's College School save much time and drudgery during their pupilage by the practical skill acquired in the workshops attached to the College, and that according to competent observers like Mr. Nussey, of Leeds, the artisans of Elberfeldt, Crefeld, and other continental towns derive great advantage from the schools of design and so-called weaving schools.

I should not fulfil my duty if I were to conclude this paper without acknowledging, though no alarmist in regard to foreign competition, that other nations, less energetic, less rich in accumulated capital and practical experience, and without the advantage of our great mineral resources, are, thanks in a great measure to their superior technical training, making relatively greater advances than ourselves in many branches of industry, and that the conviction of the necessity for such training has not arisen among ourselves a day too soon. Happily it has arisen, and in the most desirable quarters. Manchester, by the judicious enlargement of Owens College, to which its merchants and manufacturers have quite recently contributed a sum approaching 200,000*l.*; Yorkshire, by the establishment of the College of Science at Leeds, to which secondary schools of science are to be affiliated; the Company of Cloth workers, by the foundation of scholarships, and the endowment of a chair of textile technology in the Yorkshire College; the University of Durham, and the coal owners and manufacturers of the North of England, by their joint foundation of the School of Science at Newcastle; Oxford, by its patronage of the College to be established at Bristol; and the Company of Merchant Adventurers, by the aid which it is giving to the Trade School of the same city—are not only directly promoting the higher technical instruction among the populations in which their work is done, but will furnish competent teachers to the elementary and secondary schools of their own and other localities. I think there is no fear that a work of such national importance once so actively begun will suffer any relapse; but it will be in the power of this Association to promote by discussion and advice its intelligent and economical organization.

Owing to irregularities of surface, it often happens that considerable difficulty is encountered in putting a good polish on articles of brass or copper. If, however, they be immersed in a bath composed of aquafortis 1 part, spirits of salt 6 parts, and water 2 parts for a few minutes if small, or 20 or 30 if very large, they will become covered with a kind of black mud, which on removal by rinsing displays a beautifully lustrous under surface. Should the lustre be deemed insufficient, the immersion may be repeated, care being always taken to rinse thoroughly. All articles cleaned in this manner should be dried in hot dry sawdust.

MANUFACTURE OF PHOSPHURETTED STEEL RAILS AT TERRENOIRE.*

From "The Review of Mining."

M. Euverte, manager of the Terrenoire works, on being called upon by M. Jordan, the president, explained that he felt taken rather unawares in having to reply to the question that had been addressed to him. He feared that he should reply in an incomplete manner, and especially that he should not detail the facts in so systematic a manner as such a subject demanded.

But, on the other hand, he had attained on this question such an undesirable notoriety, such truly nonsensical things had been written and said of him, that, on this account, M. Euverte was not sorry to avail himself of the opportunity thus afforded him of placing matters in their proper light.

It was indeed true that during the last two years experiments on a grand scale had been made at Terrenoire, with a view to ascertain to what extent phosphorus might be introduced into steel; and these experiments had now yielded important, if not absolutely definite results.

But, in order to thoroughly understand the actual state of the question, it will be necessary to review rapidly all that has been done before, and to comprehend by what succession of ideas and investigations the present result has been obtained.

Every one who has, during the past ten years, kept up with the discoveries of metallurgical science, is quite in a position to understand that a considerable change has taken place on account of the grand discoveries of Mr. Bessemer and Mr. Siemens.

Since that period the manufacture of steel has been developed to a very large extent; and the day is not far distant when all the *materiel* of railways and works generally will be entirely of cast steel.

It must, however, be borne in mind that the present state of perfection has only been arrived at after many difficulties have been surmounted.

* Seance of the "Societe des Ingenieurs Civils."

In the year 1856 Mr. Bessemer made the first experiments in connection with his process, when the results obtained were far from satisfactory. Nothing but a hyperoxidated iron, commonly called *over-burnt iron*, was turned out of the converter.

It was then that a large number of scientific men declared that this experiment was contrary to all known theories, and that the process would never succeed.

From 1856 to 1862 Mr. Bessemer prosecuted his investigations with that tenacity of purpose which is a characteristic of Englishmen; and, at the end of 1861, the learned French professor, M. Gruner, announced to the metallurgical world the complete success of the process.

What was it, then, that happened between the years 1856 and 1862?

Two very important matters were introduced into the ordinary practice of the Bessemer process.

The inventor had recognized the necessity of only making use in the converter of a gray pig, containing silicium or manganese, and also of adding a certain proportion of manganesian pig, called *spiegeleisen*, at the end of the operation.

The credit of the invention of the last portion of the process has been disputed with Mr. Bessemer. This is not a question to be gone into here; but what is very important to determine is that there is no doubt the addition of the *spiegeleisen*, or manganesian pig, has been the real cause of the ultimate success of the Bessemer process.

At that time no definite account could be given of the part played by the manganese in the process, and it was only after a longer period of practical experience that the action of the manganese became known, and was logically demonstrated. It is now universally admitted that the office of the manganese is to separate the oxide which is abundantly formed in the metal at the end of the Bessemer process.

It will, in fact, be easily understood

that, under the action of a powerful blast, a considerable quantity of oxide of iron is formed, which interposes itself in the molten mass, and forms a decided obstacle to its malleability; it will also be understood that the manganese, the affinity of which for oxygen is well known, takes up this oxide of iron, so that the new compound mixes with the slag.

This practice of adding manganesian pig at the end of the converting operation has become invariable, and is applied not merely to the Bessemer, but also to the Siemens-Martin process.

When the Bessemer process was introduced into France the steel resulting therefrom was applied especially to the manufacture of rails, and this was the case for several years afterwards.

It will easily be conceived that the addition of a certain quantity of manganesian pig at the end of the operation had a double advantage, as far as the rails were concerned: on the one hand, the manganese fulfilled its important mission, which consists in separating the oxide; and on the other, the carbon contained in the *spiegeleisen* served to give the steel the durability suitable and desirable for the manufacture of rails.

But, after a certain amount of experience, another desideratum arose, which was to produce a very soft steel, to serve for the manufacture of plates, parts of engines, axles; in fact, all those portions of machinery which require to be made of a metal able to resist a blow.

Now, many attempts have been made to manufacture plates, etc., of steel that was more or less carburetted. But these attempts had never been successful, or, to speak more correctly, they had always been very unsuccessful. Serious accidents happened. Castings in a complete state were fractured in cooling, without its being possible to assign the cause of fracture; and finally it became necessary to exclude the carburetted steel in all cases which required a certain amount of malleability, or in which it was necessary to hammer the castings while hot.

On the other hand, it is evident to every one who knows the imperfections that exist in rolled plates and forgings of iron—imperfections which result from the necessity of there being several bands and weldings in the same piece—that the application of a cast metal to these articles offers a considerable amount of interest. There are, therefore, sufficiently weighty reasons for prosecuting this object by all possible means; and this is being done, with great perseverance, at the Terrenoire works.

The problem was, however, at first very difficult of solution; so the experimenters frequently found themselves in exactly the same position as that from which they started. In fact, when the operation is finished, manganese must be added to expel the oxide; but this very manganese introduces into the charge a certain quantity of carbon, which was contained in the manganesian pig.

If, for instance, in a charge of 3,500 kilogrammes (7,700 lbs.) of steel, 350 kil. (770 lbs.) of *spiegeleisen*, containing 9 per cent. of manganese and 5 per cent. of carbon, be introduced, 17 kil. (37½ lbs.) of carbon, representing about a five-thousandth part of the whole, will be introduced, thereby rendering the charge too highly carburetted to be malleable.

If less manganesian pig be added, the charge will contain, it is true, less carbon; but then the manganese will not be present in sufficient quantity, and the metal will be but slightly malleable. This is, then, a regular difficulty, out of which the only way to escape is by arriving at a mixture of metals rich in manganese, by which, without adding large quantities of carbon, a sufficient dose of manganese would be afforded. The production of a mixture rich in manganese was then found, *a priori*, the solution of one of the most important points in the progress of metallurgy. At the very moment that this solution of the question at the Terrenoire works was made known it happened, as has frequently been the case in the history of human industry, that in another place the problem was in a great measure solved. In fact, at this very time—that is to say, at the end of 1865—Mr. Bessemer made known to the Terrenoire Company the existence, in the neighborhood of Glasgow, of works producing a *ferro-manganese*, containing from 25 to 30 per cent. of metallic manganese, which had been obtained by the process of Mr. Henderson, the inventor. About the same time the German technical journals published the fact that a manufacture of ferro-manganese, by the process of M. Oscar Prieger, was established at Cologne. The ferro-manganese produced at this establishment contained a uniform proportion of 75 per cent. of metallic manganese; it was made in crucibles, in a very slovenly manner, and was sold at 6 francs per kilogramme (about 2*s.* per lb.). Trials were made without the slightest delay at Terrenoire works, where these mixtures, which were found exactly to realize the desideratum before reasoned out; the results were exactly what one had a right to expect, and, especially with the ferro-manganese, a cast metal was obtained having all the qualities of the English homogeneous metal, containing but a slight trace of carbon, and lending itself remarkably well to all the uses of industry. The problem was solved in principle; but there was still much to do before arriving at a solution that was sufficient for manufacturing practice. In fact, for one reason or other, the manufacture was suspended in England; the price of the German spiegeleisen became much too high to be used with commercial success, and it would have been impossible to have procured the ferro-manganese unless the Terrenoire Company had come to an understanding with the inventors as to the right of founding a manufactory in France. This manufactory, definitely established in 1869, after many experiments and difficulties, has now got into thorough working order. The Henderson process, taken as the basis of operations, was brought to successive stages of improvement, and from the year 1871 ferro-manganese containing from 40 to 42 per cent. of metallic manganese has been produced at the Terrenoire works at the rate of 2 to 2½ fr. per kilogramme (9*d.* to 11½*d.* per lb.). Recent improvements will allow of the mixture to be produced containing as much as 50 per cent. of metallic manganese. The problem is now, therefore, thoroughly solved, and extra-malleable cast steel can be produced in a regular and satisfactory manner, suitable for the manufacture of plates, parts of engines, and military and naval ordnance, which can be used with safety, and which possess all the qualities that can be desired of resistance and elasticity. It thus happens that, at the present time, the State Marine requires, and also obtains, in large quantities, plates having a resistance to tensile strain of 45 to 50 kilogrammes per square millimetre (63,813 to 71,220 lbs. per square inch), and yielding to the extent of 20 to 25 per cent. before fracture.

The best brands of iron that are known have never given such results as the above; they are, besides, liable to the very great objections of piling and imperfect welding, so that no one will venture to deny that the production of a malleable steel possessing the properties above enumerated is one of the great achievements of modern metallurgical science.

M. Euverte here remarked that it might appear somewhat strange that in replying to a question relative to phosphuretted rails he should so far digress from the subject as to speak of the production of malleable cast steel by means of ferro-manganese.

He could not, however, avoid doing this, as the two questions were indissolubly connected, and he hoped to show that unless alloys rich in manganese had existed the phosphorus question applied to rails would still have been unsettled.

The investigations relating to phosphorus at the Terrenoire works date from a tolerably distant period.

At the end of the year 1869 one of the most distinguished leaders in the field of applied science in France, M. de Wendel, had undertaken some investigations on a large scale at Hayange, which were actively prosecuted, on the possibility of producing steel from ore extracted from the large mineral deposits of the Moselle, and containing a high percentage of phosphorus.

Pigs run under special conditions had been puddled with the greatest care, and the products thereof had been remelted in a Siemens-Martin furnace, and run into ingots for the manufacture of rails.

As M. de Wendel was not in possession of a set of rolls suitably arranged for the rolling of these steel rails, he entrusted the work to the Terrenoire Company.

This rolling took place in due course, and the result of the first attempt, imperfect though it necessarily was, gave the first indication that phosphorus was not entirely incompatible with steel, and that investigations in this direction should not be brought to a standstill on account of difficulties, real enough, it is true, but which should not be absolutely insurmountable.

M. Euverte here stated that, personally, he had always been convinced that phosphorus need not be an absolute cause of inferior quality in steel, especially in the proportions he had mentioned in the first place.

In fact, it was well known to those who had studied the subject of iron manufacture in the different French districts, that the phosphoric irons were those which worked best in the rolls, and which best took any form it was desired to give them. These irons, it was true, especially in the form of rails, possessed a certain amount of brittleness when subjected to tests of impact; but this drawback had been much diminished by the progress in puddling and rolling during the last fifteen years, and no one would deny that phosphoric irons had entered the market to a considerable extent.

How, then, had it happened that, in the manufacture of cast steel, people had stumbled against such an absolute impossibility? How was it that the assertion had come to be made, that even the smallest proportion of phosphorus completely destroyed the malleability of steel?

Evidently there was here an unknown quantity to evolve; the particular causes had to be discovered which rendered phosphorus absolutely incompatible with steel, and this was one of those cases in which, given preceding experience, it might be said, "*Seek, and you shall find.*"

The experiments made on the cast steels produced at Hayange were the first result which showed that the object was not impossible to be attained; nor was it long before other trials more decisive took place.

For some years past, M. Tessié, of Motay, who was well known for his spirit of investigation and discovery, had undertaken, at Commines, Nord, some metallurgical experiments, with a view to eliminate the phosphorus from the pig. These experiments were ultimately transferred to Terrenoire, where they have been prosecuted up to the present time.

A conclusion was arrived at, however, which is often the case under similar circumstances, viz., that it is not so easy to get rid of the phosphorus by a rapid process, more or less analogous to that of Bessemer; but it was discovered, on the other hand, that under certain determined circumstances, the phosphorus incorporated with the steel produced no injurious effect.

On phosphuretted substances being introduced, in tolerably large proportions, into a Siemens-Martin furnace, and the operation being completed with ferro-manganese, containing 42 per cent. of manganese, or rather with spiegeleisen, it was found that the metal obtained was malleable, and of good merchantable quality.

This experiment, resumed at different times, always yielded the same results; and it is from the result of a series of operations of this nature, that the following dictum has been arrived at by those conducting the investigations at Terrenoire:

Phosphorus may be introduced into cast steel, provided that the carbon be eliminated; and the less carbon there remains, the more phosphorus may be left.

This law, taken generally, is absolutely true at the present time, but it requires to be more precisely stated, so as to show positively the quantum of phosphorus which may be allowed to remain in a cast steel without impairing its essential qualities of malleability, resistance, etc.

Numberless experiments have been made with a view of arriving at these several particulars, and it is not yet possible to get out positive formulæ on the subject. For this reason it is much to be regretted that a premature publicity should have given to this question an aspect which it cannot really even now assume. People have even been induced to say and write that, by means of phosphorus, as good a quality of steel can be produced as any now in use, which is an assertion that must be met by direct denial.

That future experience will ultimately reveal valuable properties in steels containing phosphorus, is no doubt possible, and perhaps probable; but the question cannot be decided at the present time.

It must be allowed at once, that though it is desirable to be able to introduce phosphorus into steels, in order to utilize for their production raw products hitherto considered injurious, at any rate *as little as possible should be admitted.*

The result of all the experiments made

at Terrenoire is that the physical properties of the new metal thus obtained present peculiarities which merit an attentive study. The opinions formed thereon are not yet sufficiently definite to be put into form: but the subject of a future communication to the Association will be hereby afforded. For the present, M. Euverte must be content with observing that a field is here opened for research of great importance; and this is indeed an occasion to recall the words made use of by the learned President of the Association, during his inaugural speech: "*The sciences which may be called the molecular physics and mechanics of iron are indeed in their infancy.*" This is a great truth, and thanks are due to Mr. Jordan for having proclaimed its importance, and also for having drawn thereto the especial attention of metallurgists. That it is one of the departments of science and industry which are totally deficient in classified and reliable data, is admitted by all. The criterion of comparison is at fault in most cases, and a methodical investigation should be brought to bear upon this subject with a keenness of intellect with which few men are gifted. In fact, a specific talent for research should be developed and cultivated by each individual in and for himself.

The experience acquired by the numerous experiments on phosphoric steel already made at the Terrenoire Works, and those which are undertaken every day, keep alive in the most evident manner the importance of a study of the physical properties of metals. The results of the experiments will no doubt in time lead to more precise information; but all that can be stated at present, to keep within the bounds of strict veracity, is, that a steel containing about *three thousandth parts of phosphorus, and one and a-half thousandth part of carbon*, is very malleable, and may be used for the manufacture of rails of very good quality.

It may, perhaps, be said that a metal containing only *one and a-half thousandth part of carbon* is not steel. This is, perhaps, true, and it might be useful to raise the question if the nomenclature should not be modified, and whether it be well to retain the name *steel* for metals which contain scarcely any carbon, which do not become at all hard by being tempered, and resemble iron in every respect. The authorities of the navy have already given the name of *cast metal* (*métal fondu*) to the soft plates which they are now ordering in great quantity from the works of Terrenoire and Creuzot; and it may be asked whether it would not be well to adopt this term generally.

To sum up, it is now quite determined that cast steel may contain a certain proportion of phosphorus, without ceasing to be malleable, but at the same time retaining their valuable properties of resistance.

The precise proportions of phosphorus and carbon which may enter into the composition of a metal of good quality, and the different physical properties of this metal, will have to be definitely determined at some future time.

But we are now in possession of the principal fact, and also of this other fact, that a mixed metal, rich in manganese, can be satisfactorily produced; so that we may consider the problem solved, *that phosphorus may be introduced into the steel on condition that no carbon be added*, or at least with the addition of as little as possible of the last-named substance.

It would be difficult to foresee, positively, at the present time, what will be the ultimate consequence of the new facts which have just been detailed. It is not difficult to believe, however, that, taking the question in its broadest light, the results to be achieved may be very considerable.

One fact is, at any rate, evident to those who have followed the progress, not only of the metallurgy, but also of the world, during the last ten years, that a great change is taking place, by the gradual substitution of steel for iron.

It is equally certain that this change marks an actual progress, since the object is to replace a metal which is imperfect in its physical constitution, by another, which is stronger in every respect, and which, especially in the form of railway bars, has a durability from five to ten times greater, without an increase in cost proportionate to the advantage obtained.

But if the practice had been persisted in of only making use of first-class ores for the production of cast steel, the progress in question would have been considerably hindered.

In dealing with the question what would become of the old iron rails if all the railway companies were to determine henceforward to use none but steel, no great amount of reasoning will be required to show that this course might give rise to serious difficulty.

If, however, it be proved that the old rails, judiciously mixed, can be recast and made into new, surely one is justified in considering that a great problem has been solved, since it renders easy of accomplishment a change which all are agreed is desirable.

But if, especially, it be calculated that the old rails are now represented by the following figures: France, three million tons; England, six million tons; America, ten million tons; and the rest of the world, ten million tons—that is to say, at least *thirty million tons of rails made of bad iron, which might be turned into cast steel rails*—the importance of the result at which it is possible to arrive by applying the principles enunciated above, is still more striking.

There is still one other consequence arising from these new discoveries, which is not without importance, and which deserves to be taken into serious consideration. Since the Bessemer and Siemens-Martin processes have come into common use, great quantities of cast steel have been turned out under different forms; but no matter to what use they have been put, rails, plates, axles, parts of engines, or what not, the same class of ores has always been employed, and always those of superior quality. It is this circumstance which caused the learned and lamented Rivot to say: *It is contrary to commercial common sense to make rails out of Mutka ore.* This is perfectly true; but up to the present day, one had reason in replying to M. Rivot: One does as one can.

From the present time, however, these conditions will be considerably modified. A classification of ores will be made, and each will be applied to the purpose for which it is best suited. The different samples of cast steel will also be classed according to their quality, as is now the case with the different brands of iron; and when this is done it will be possible to say that metallurgical practice has been placed upon a rational basis, and that it is in a position to turn to best account all the elements at its disposal.

During the discussion which followed this valuable communication, the President, referring to the publicity of which M. Euverte complained at the beginning of his speech, asked if it were true, as was reported, that some railway companies had already received several thousand tons of cast steel rails containing three or four thousandth parts of phosphorus. Also, if cast steel had been produced from phosphoric ores so as to justify the expectation of certain metallurgists who already see the centre of the steel manufacture in France transferred from the basin of the Loire to that of the Moselle.

M. Euverte replied that the quantity of rails cast from old *materiel*, and supplied to the railway companies, had been greatly exaggerated; that in the manufacture, those old rails had been chosen which offered the least difficulty in the process; and that even if true, that metal containing four millionth parts of phosphorus has been rolled into rails (which were however brittle), the rails sent out were far from containing this proportion of phosphorus. Steel had not yet been produced from phosphoric ores, but the speaker was not without hopes of seeing this brought about. He added that the important point, one which required steady application in order that sound progress might take place in their working, was the molecular condition of the new kinds of steel, which presented some strange phenomena hitherto unexplained.

M. de Hastaing asked how the old rails were treated in this process.

The President believed he was able to answer this question; it was by means of the Siemens-Martin furnace. In order to carry on the discussion he then remarked that the advantageous employment of phosphoric irons, in rails which were piled and welded, was a well-known fact: as, for instance, the rails of the Moselle, of the Ruhr, and other places. Karsten, who may be regarded as a classic writer on metallurgy, said that irons may be applied to certain purposes if they contain three, and even five millionth parts of phosphorus.

The Terrenoire Company appeared to have found means, thanks to ferro-manganese, of working up welded phosphoric rails, and converting them into cast phosphoric rails; and this was a considerable step in metallurgic progress.

Of course the question was not one of

designedly introducing phosphorus into the steel, but of turning to account what one was obliged to leave therein.

The presence of manganese in certain samples of steel was regarded by distinguished metallurgists in a favorable light, inasmuch as they attribute both malleability and elasticity to its presence.

As regards the definition of steel, the President had long been of opinion that the word should only be applied to malleable cast metal, and that it might be used for all metals of this class. He saw no greater difficulty in designating by the same name the fine steels of Dannemora, and the new class of steels of Terrenoire, than in including under the general name of *iron* the Swedish wire for the teeth of cards and the soft iron of the Moselle, or under the general name of *pig* iron the black Scotch pig, and the German spiegeleisen. The art of the engineer and the metallurgist consisted in knowing exactly how to turn to its proper account each class of matter.

M. Euverte was entirely of this opinion, and regretted that a mischievous publicity had attributed to phosphoric steel all possible qualities.

As to the introduction of phosphorus into the metal for making steel rails, this cannot be avoided when it is required to work up old rails. When old phosphoric rails are added to a charge consisting from the first of a considerable quantity of good metal, the mixture cannot fail ultimately to contain some portion of phosphorus; but in order to have as little of this substance as possible, the speaker, if he had to work up all the old rails of all the French railways, for instance, would contrive the mixture so as to reduce the phosphorus to a minimum.

As regards the question of malleability, the greatest enemy of which is oxidation, M. Euverte considers that the office of manganese is especially to counteract the oxidation or to dispel the oxide.

The President, in conclusion, thanked M. Euverte for his important and very interesting communication, and begged him not to forget that he had promised to continue it at some future time.

FOUNDRY CRANES.

From "Iron."

It is the author's opinion that less is known, and much less done, in the arrangement of the lifting power, as applied in a foundry, so as to meet the especial requirements thereof, than in any other department of the engineering and iron trade. Generally speaking, foundries are so ill constructed, that to erect therein a proper system of lifting power is almost out of the question. Very often foundries are made up of shreds and patches of buildings, so ill adapted for their purpose that it is almost impossible to erect therein anything like a proper foundry crane, and all sorts of strange erections are fixed in them, and only do the mimimum amount of duty, with a maximum amount of power. This not unfrequently happens from the idea that any person can construct and manage a foundry, without thoroughly understanding the principles of the art of founding, or yet a correct knowledge of the laws of mechanics.

When we first went into a foundry nearly half a century ago the old cranes had ropes instead of chains; and such was the aversion to the use of chains on cranes at that time that you could hardly induce a sand moulder to lift his mould with them for fear of shaking his mould to pieces, so unsteady were the then existing cranes that had chain falls upon them. And when we look back at the strange pieces of rude mechanism that had to do duty for foundry cranes we do not wonder at the moulders of that day objecting to use chains, or clinging so tenaciously to ropes; and yet rope falls had serious drawbacks, for they had to suspend underneath the bottom block a sheet iron cover to keep the heat of the molten iron in their crane ladles from burning the ropes. But from the various accidents daily arising from those old-fashioned cranes, and the ever-increasing demands for larger castings through the rapid progress of engineering, much progress has been made in improving the jib cranes by making them to wind the blocks out and in to any radius, so that they could lift a mould or casting at any point within the radius of the cranes. Many of the arrangements were then very imperfect, but others succeeded of a more admirable description, yet all had to be worked by hand power. Subsequently steam power was applied to them, in some cases by connecting the working gear to the main shafting of the engine. Getting power by this method was a great convenience, because it was less expensive, more powerful, and did a much greater amount of useful work. But power thus applied was found not sufficiently accurate for a foundry, or to meet the ever-varying requirements of moulding. Subsequently small steam engines were fixed to the cranes, which enabled the engine man to execute any movements as to speed, stopping, or reversing, as were required. Many of these cranes are excellent, but some of them are far otherwise.

Another motive power also has been applied to jib cranes, and that is Sir William Armstrong's system of hydraulic power; and for ease, precision, and rapidity of motion I consider the system to be in the foremost rank as to arrangement of jib cranes for the use of a foundry. Such cranes are very costly in their construction, no doubt will require a good deal of keeping in repair, must be repaired with skill, and are not always suitable for every foundry, but they are worthy of admiration. Small steam cranes can more easily be applied in many cases, and can either get their steam from a fixed boiler on the works or a small one attached to the crane.

Another description of crane has come much into use in foundries, and that is the overheard travelling crane. It has many advantages over the jib crane, especially in large foundries. It, in the first place, does not take up any of the available space on the shop floor as a fixed crane does; it has a much wider range of usefulness, having the extreme length and breadth of the building, whereas a jib crane can only be useful within the limit of its own circle, and a great portion of that is lost near the centre; and also it does not require, as in a large shop, to change the load from one crane to another. At first overhead cranes were very imperfect, simply comprising a pair of traversing beams and a common crab for lifting on the top; but in course of time the arrangements were so much perfected that all the motions were directed by one man, and were made to work with great accuracy. The very imperfect ones may be passed over. Some have been modified. For instance, they have been worked from the floor by means of endless chains so that men might not be on the top of the crane; but they were not a success, as they wanted all the elements of a useful foundry crane—ease, regularity, and rapidity of motion. There was another where all the motive power was applied by the men from a small hanging platform under one end of the beams; and for a hand-power crane much could be done thus wise. But the best hand-power overhead trailing cranes seen by us especially adapted for a foundry were designed by Mr. D. Thompson, when manager to Messrs Simpson and Co., of Pimlico, London; these have all the requirements of a real foundry crane worked by hand.

The next thing was the application of steam power under various modifications to overhead travelling cranes. In some instances this was effected by applying the power from a fixed engine, and working the shafting and bevelled gearing with the machinery; but this method is not suitable for a foundry, as it is wanting in the element of making the motions at any rate of speed required with precision. Another method, which has been, and is now, very much in use, is by an endless rope running at a very high velocity, worked by a fixed engine, and by the contact of friction shears producing the various motions. This system also has many drawbacks, the greatest being the amount of wear and tear upon a rope running at such a great speed. Although the arrangements of this system have many modifications, yet none that we have seen fully meet the requirements of a foundry; for one cannot obtain the ever-varying amount of speed in all its changes as required, or stop or start suddenly any motion that may be needed. We have well tested them, but they are not to our mind a perfect foundry crane.

The most complete steam travelling

crane for a foundry we have seen was made by Messrs. J. and H. Ellis, of Salford, Manchester, for the foundry of the Fairbairn Engineering Company, Manchester; it has a pair of 6-in. cylinder engines and boiler attached to it at one end of the beams, and all under the control of the engine-driver; and for accuracy of work, ease, and rapidity, we have seen none to equal it. In some of the details of arrangements, improvements no doubt can be made, but the principle upon which it is constructed, as far as our own experience is concerned, justifies the highest commendation.

ON THE USE OF STEEL RAILS, AND THE NEW CLAUSES IN THE SYSTEM OF TESTING IN RUSSIA.

From the "Universal Review of Mining."

The rapidity with which the system of Russian railways has been completed has latterly raised the question of the use of steel rails instead of iron ones for the new lines. This question has been decided in favor of the former; for the Russian Imperial Administration has approved of the construction with steel rails of the railways from Wjasma to Tula, Rjask, and Jeletz, and from Morschansk to Siezran, comprising a length of 1,200 kilometres.

The ministry of finance fully guarantees the preference shares of these railways, amounting to three-fourths of the entire capital, as also, for a term of fifteen years, the remaining shares, forming one-fourth of the capital. This circumstance evidently proves that the government regards the use of steel rails as highly advantageous, notwithstanding it involves an additional payment to the contractor of 1,023 roubles per werst.

It is astonishing that in other countries, especially in Austria and Germany, where the traffic is more considerable than in Russia, the same conclusion has not been arrived at. We are convinced that the adoption of the same measures in these countries would diminish the subsidies that have to be paid out of the public treasury.

The weight of the steel rails for the new Russian railways is 26.88 kil. per current metre. These rails are intended to replace iron ones weighing 32.26 kil. per current metre.

After a long discussion, there has been adopted, as a type, one of Vignoles' rails, which is 107.95 millimetres high, 95.25 millimetres wide at the foot, and 12 millimetres thick in the middle.

The measurement adopted is a difficult one to roll; but it is convenient in this respect, that it admits of the rails being solidly fished. The length of the rails has been fixed at 24 English feet. With a view to their transport, it is only after some hesitation that it was decided to give them this length, seeing that the normal length of the Russian vehicles is only 21 English feet, or about 24 feet including the buffers.

Moreover, it is always more economical for railway managers not to order short rails, as the net cost per ton is much higher for rails of moderate weight, in keeping to the ordinary length of 21 feet. For this reason, the Americans, who are practical men, have given to light rails a length of from 27 to 30 feet.

Fixing the standard of the test system has also given rise to serious observations, especially with respect to tests. The Commission, which was composed of the most experienced railway engineers, decided, after long debates, that steel rails, weighing 26.88 kil. per current metre, should stand the following tests:

1*st Test.*—The rail, placed on supports 3 feet apart (0.912 metre), and bearing for five minutes a weight of 16½ tons, ought not to give way more than 0.15 of an inch (3.75 mil.). After withdrawing the load, the permanent bend should not exceed 0.04 of an inch (1 mil.).

2*d Test.*—The rail, placed on supports 3½ feet apart (1.06 metre), should bear, without breaking, the shock of a battering ram of half a ton, falling from a height of 9¾ feet (2.96 metres).

Iron rails of 32.26 kil. per current metre were subjected to the same tests, but only with half the loads and weights.

We applaud these results; they prove, we think, that in Russia technical men have examined the question conscientiously and profoundly.

It is necessary to observe that the climate of Russia requires rails of greater solidity and resistance than those used in other countries.

It has been thought, during late years, that the maximum of resistance would be obtained by subjecting the rails to the test of a tremendous shock; but experience has shown that both iron and steel rails, which had borne the test with ease, and had broken very little in being used, lasted only a short time in consequence of their hardness.

For this reason, the test of the shock which was formerly applied, of letting a battering-ram weighing 1,000 kil. fall from a height of 5 metres, has been reduced to 5 per cent. for rails of 28 kil. per current metre. A corresponding reduction has been made for lighter profiles.

The flexion test appears to us to be safer than that of the shock. The French records contain more rational rules in this respect, containing, as they do, a certain number of strokes, falling from a different height, which determine at the same time the maximum of flexion. By this means, rails of sufficient hardness are sure to be obtained, whereas it is to be feared they may be got too soft in subjecting them to a violent concussion without indicating the arc of flexion.

Steel rails have answered well in Russia.

The Nicolas railway, on which the greatest number has hitherto been employed (96,000 rails), after three years' service, shows a maximum refuse of 0.87 per cent., and a minimum of 0.03 per cent. This result is all the more remarkable as the Nicolas railway (a double line) yields a daily revenue of 182 francs per kilometre; it may therefore be ranked among those possessing the largest traffic in the world.

A question not less important for the solidity of steel rails, is the position of the notches in which the fastenings of the rails have to be inserted. It will be interesting to show the results obtained by careful experiments relative to the resistance of steel rails notched in different ways.

These results show what a considerable influence the position of the notches has upon the resistance of the rails. Railway managers should give their special attention to this point, because a large proportion, we may say the largest proportion, of rail fractures arises from the position of the notches.

EXPERIMENTS ON THE RESISTANCE OF STEEL RAILS DIFFERENTLY NOTCHED, ON THE PARIS AND LYONS RAILWAY.

Trials by shock on Rails with or without notches with a hammer of 300 kil.

Dates.	Bessemer Steel.	Height of fall determining the rupture.
	Steel Rails, with two pentagonal notches:	
1871.		Metres.
July 24.	Notched with a drilling machine........	0.256
" "	Do. do. and filed..	0.300
" 28.	Without notch..........................	2.500
" "	Notched with a drilling machine........	0.350
" "	Do. do. and filed..	0.600
" "	Without notch..........................	3.000
	Steel Rails with only one semi-circular notch:	
July 28.	Notched with a cutting file..............	0.800
" "	Without notch..........................	4.000
Aug. 10.	Notched with a drilling machine........	0.500
" "	Do. do. and filed..	0.550
" "	Without notch on a length of 5.96 met..	3.620

Average Resistance:

	Without notch.	Notched with a drilling machine.	Notched with a drilling machine and filed.	Notched with a cutting file.
Steel rails with two pentagonal notches........	2.75	0.30	0.45	....
Do. with a single semi-circular notch..........	3.96	0.50	0.83	0.90

From these results it is evident that steel rails, when notched, present a much more feeble resistance to the shock than rails without notches, or than those only notched at one end.

We may say, in conclusion, that in 1872, 70,000 tons of steel rails were ordered for Russian railways. The Creusot manufactory has had the lion's share of this order, which had to be delivered in 1873–'74. It forms a new outlet opened to this manufactory, which will probably be durable, seeing that English manufacturers do not care to make rails whose weight, as is the case here, does not exceed 26.88 kil. per metre.

THE NEW METHOD OF GRAPHICAL STATICS.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

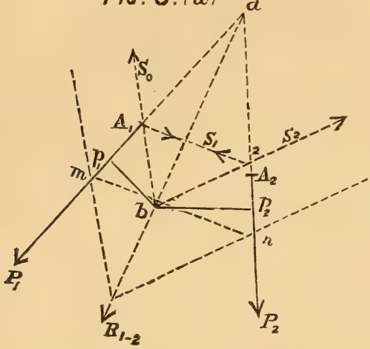
By A. J. DUBOIS, C. E., PH. D.

CHAPTER II.

FORCES LYING IN THE SAME PLANE—DIFFERENT POINTS OF APPLICATION.

16. RESULTANT OF TWO FORCES IN A PLANE—DIFFERENT POINTS OF APPLICATION. Heretofore we have considered forces having a common point of application, and have seen that in any case the direction and intensity of the resultant is easily found by *closing the force polygon.*

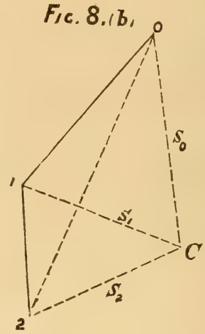
FIG. 8. (a)



But suppose we have two forces P_1 P^2 having *different* points of application A_1 A_2; required the position and direction of the resultant [Fig. 8]. *Any force acting in a plane may be considered as acting at any point in its line of direction.* P_1 and P_2 may then be supposed to act at their common point of intersection a_1 and through *this* point the resultant should pass. The case reduces therefore to a common point of application. The resultant is given in intensity and direction by the force polygon (*b*) and its position is determined by the point of intersection *a.* At this point, or at *any point* in the line through *a*, parallel to 0 2, the resultant may be supposed to act.

But the direction of the forces may not intersect within reasonable limits, or the forces may be supposed parallel to each other, so that they *may not intersect at all.* In any case the *force polygon* will give the intensity and direction of action of the resultant, but its position in the plane of the forces remains to be determined. We have seen [Art. 5] that we can decompose a force into two components in any desired directions, by choosing a "*pole*" and drawing lines to the beginning and end of the force in the force polygon. Let us choose then a *pole* C [Fig. 8 (*b*)] and decompose the resultant thus into two forces given in intensity by 0 C and 2 C. The forces P_1 P_2 being supposed to act at the points A_1 A_2 in the common plane, at what point in the plane and in what direction must the resultant be applied to keep this plane and hold the forces in equilibrium? The direction of action of the resultant is given at once from the force polygon [Art. 5 (*b*)]. It must act in a direction from 2 to 0, and must be equal to 2, 0, taken to the scale of force. Now at *any* point in the line of direction of P_1, as for instance A_1, let us suppose the component given by C_0 to act. What is the resultant of P_1 and C_0? A glance at the force polygon gives us 1 C, because this line closes the polygon made by C_0 $_{0\,1}$ and 1 C. At A_1 then the three forces S_0 (parallel and equal to C_1) S_1 (parallel and equal to 1 C) and P_1 are in equilibrium, and there is no tendency of the point A_1 to move. But 1 C or S_1 may be considered as acting in the plane at *any* point in its line of direction; therefore at 2 its intersection with P_2 prolonged. Suppose at 2 S_2 or 2 C to act. We see at once from the force polygon that 2 C C_1 and P_2 are in equilibrium. There is therefore no tendency for the point 2 to move, and the two forces P_1 P_2 are then in equilibrium with C_0 1 C C_1 and 2 C. But since the resultant of C_0 and 1 C or of S_0 and S_2 is also the resultant of the forces, and since it must moreover act throughout the point of intersection of S_0 and S_2; we have only to prolong these lines to inter-

FIG. 8. (b)



section *b*. Through this point the resultant $R_{1\text{-}2}$ must pass and acting *downwards* (from $_0$ to $_2$) as indicated in the Fig., it *replaces* P_1 P_2. Acting upwards it would hold them in equilibrium. We thus easily find the point 2 in the plane at which 2 C or S_2 must be applied, *when* C_0 *or* S_0 *acts at* A_1, and S_0 S_2 are thus found in proper relative position. The position, intensity, and direction of the resultant are thus completely determined.

Had we taken any *other* point than A_1, as the point of application of C_0, we should have found a different corresponding point for application of 2 C, but in any case the prolongations of 2 C and C_0 would intersect upon the line *a b*, prolonged if necessary. The same holds true for any position of the "*pole*" C. This construction is evidently general

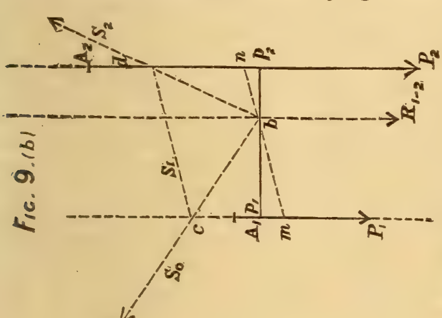


Fig. 9. (b)

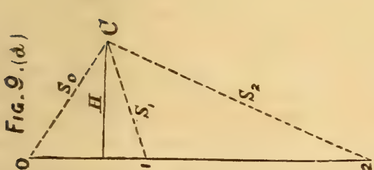


Fig. 9. (d)

whatever the position or whatever the number of the forces. We thus obtain a number of points along the line *a b;* that is, the resultant also may act at any point in its line of direction.

[Note.— *That b is a point in the resultant of* P_1 *and* P_2 *can be proved in a method purely geometrical. In the two "complete quadrilaterals"* 0, 1, 2, C, *and* A_1 *b* 2 *a the five pairs of corresponding sides* 0 1 *and a* A_1, 1 2 *and a* 2, 2 C *and b* 2, C_0 *and b* A_1, C 1 and A_1 2, *are parallel each to each, therefore the sixth pair* 0 2 *and a b must also be parallel; b is therefore a point of the resultant passing through a, parallel to* 0 2.]

17. The above construction holds good equally well for parallel forces. By means of it we find in Fig. 9 (*a*) and (*b*) and Fig. 10 (*a*) and (*b*) the resultant of a pair of parallel forces, in the first case, both acting in the same direction; in the second, in opposite directions.

In both cases we have simply to choose a pole C, and draw S_0 S_1 and S_2. Then taking any point *c* in the line of direction of P_1, as a point of application for S_0, draw through this point S_1, thus finding *d*, the point of application for S_2. S_0 and S_2 prolonged, intersect upon the resultant, whose intensity, direction, and position thus become fully known.

18. Property of the point b. It is plain that thus a point of intersection *b*, through which the resultant must pass,

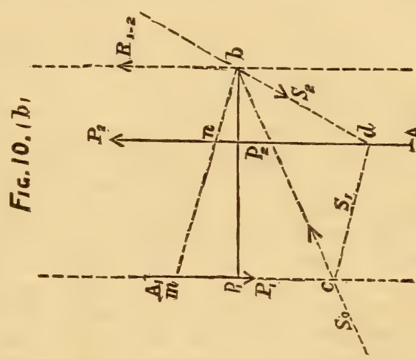


Fig. 10. (b)

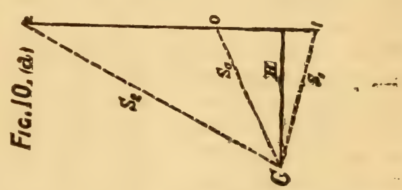


Fig. 10. (d)

can always be found, provided S_0 and S_2 do not fall together in the force polygon, or intersect without the limits of the drawing. By properly choosing the position of the pole C, this can always be avoided if the points 2 and 0 in the *force polygon do not themselves coincide.*

The point *b* Figs. 8, 9, and 10 which by reason of the arbitrary position of the *pole* may lie anywhere upon the resultant, has a remarkable property. If we draw a line *m n* through this point parallel to S_1, and let fall from it perpendiculars p_1 and p_2 upon P_1 and P_2, then in all three cases and therefore generally, the triangle *c m b* is similar to 0 C 1, and *d b n* is similar to 1 C 2. Hence we have the proportions—

0 1 : 1 C : : $c\ m$: $m\ b$, and
1 C : 12 n : : b : $n\ d$.

From these proportions we find

0 1 : 1 2 : : $c\ m \times n\ b$: $m\ b \times n\ d$.

Now the triangles $c\ m\ b$ and $d\ n\ b$, have the same height above the base $m\ n$; the bases $m\ b$ and $b\ n$ are therefore proportional to their areas. But their areas are equal to their sides $c\ m$ and $n\ d$ multiplied by p_1 and p_2 respectively. Hence we have from the above proportion—

0 1 : 1 2 : : $n\ d \times p_2$: $n\ d \times p_1$ or
0 1 : 1 2 : : p_2 : p_1

That is, *the perpendiculars let fall from any point of the resultant upon the components, are to each other inversely as the components.* Regarding any point of the resultant as a centre of moments, the moments of the forces then are equal, and of course the forces themselves are inversely as their lever arms.

19. Equilibrium Polygon.—If we consider the forces P_1 P_2, Figs. 8, 9 and 10, held in equilibrium by their components C_0, 1 C, and 2 C, C 1, which act parallel to the lines S_0 S_1 and S_2; then regarding the line S_1 or $c\ d$ as part of the material plane in which the forces act, C 1 and 1 C balance one another, and cause either tension or compression in $c\ d$. Suppose the resultant R is to act so as to cause equilibrium, or prevent the motion of the plane due to P_1 and P_2. Then R must act upwards in Figs. 8 and 9, and downwards from 2 to 0 in Fig. 10. In Figs. 8 and 9 then, S_0 and S_2 act *away* from c and d (Art. 4), and in Fig. 10 *towards* c and d. Following round the force polygon, we find in the first two cases $c\ d$ in *tension*, in the last $c\ d$ in *compression.*

In the first two cases, the points of application c and d of S_0 P_1 and S_2 P_2 if connected by a *string* stretched between c and d will be perfectly fixed and motionless; while in the latter case, the string must be replaced by a *strut.* In case of three or more forces the polygon or broken line which we obtain, by choosing a pole, drawing lines to the beginning and end of the forces in the force polygon, and then parallels to these lines intersecting the lines of direction of the forces in the *force diagram*, we call the "*string*" or "*funicular polygon*," or the "*strut polygon*," according as the forces act to cause tension or compression along these lines. We can apply to both cases the general designation of polygon of equilibrium or "*equilibrium polygon.*" The perpendicular let fall from the pole C *upon the direction of the resultant* in the force polygon, we call the "*pole distance*" and shall always designate it by H. The straight line joining the points c and d, or the beginning and end of the equilibrium polygon, we call the "*strut*" or "*tie line*" or generally the "*closing line*" and designate it by L. The convenience and application of these terms and conceptions will soon appear. In the present case of only *two* forces, the equilibrium polygon becomes a straight line and coincides with L, or $c\ d$.

[Note.—We repeat that in order to determine the *quality* of the strain in $c\ d$, we have only to follow round the force polygon in *the direction of the forces*, and then refer to the force diagram. Thus Fig. 9, at c, P_1 S_0 and S_1 act, and are in equilibrium. The corresponding closed figure is given in the force polygon (a). S_0 acts away from c, P_1 acts downwards from 0 1. Continuing this direction we find S_1 acting from 1 towards C. *Reversing* this direction (Art. 4), we find that the resultant which *replaces* S_0 and P_1 acts from c to 1. Referring now to the force diagram (b), and transferring this direction to the point c, we find this resultant acts to pull c *away* from d or *contrary* to the direction of the force 1 C which replaces S_2 and P_2. The strain in $c\ d$ is therefore tension.

A better way of arriving at the same result, is to consider the triangle $c\ b\ d$ as a jointed *frame* which holds in equilibrium the forces P_1 P_2 and $R_{1\text{-}2}$. Then the strains in any two pieces $c\ d$, $c\ b$, meeting at a point, *are in equilibrium with the force or forces acting at that point.*

We have then the force P_1 acting at apex c, decomposed into strains along $c\ b$ and $c\ d$ (Art. 5) represented by C_0 and 1 C in the force polygon. All three are in *equilibrium.* P_1 acts *down.* Follow *down* then from 0 to 1 from 1 to c and c to 0. Refer back now to apex c of the frame and transfer these directions. The strain in $c\ d$ acts *away* from the apex c and is therefore in tension, while the piece *c b* would be in compression, since the direction of C_0 is *towards apex c.*

See also "practical applications" of the preceding chapter for illustrations of this.

In the same way follow round 0 1 C Fig. 10 (*a*) and refer to (*b*) and S_1 is in *compression.*]

20. CASE OF A COUPLE.—In Article 18 we remarked that the pole can always be chosen in such a position as to give S_0 and S_2 intersecting within desired limits, *provided* that S_0 and S_2 or the point 0 and 2 do not *coincide.* This case however actually happens, with a pair of equal and opposite forces—that is, with a *couple.*

Thus in Fig. 11 we have two equal and opposite forces P_1, P_2.

The force polygon closes: therefore the resultant is zero. S_0 and S_2 are parallel, hence their point of intersection in the equilibrium polygon is infinitely distant. By changing the position of the pole, we see that S_0 and S_2 may take *any* positions in the plane.

Two forces therefore which form a couple *cannot be replaced by a single force.* Their resultant is an indefinitely small force situated in any position in the plane of the forces, at an infinite distance.

CONDITIONS OF EQUILIBRIUM.—If then, similarly to Art. 4, any number of forces lying in the same plane and having different points of application, are in *equilibrium*, the force polygon always *closes.*

But inversely, if the force polygon closes, *it does not follow that the forces are in equilibrium*—a couple *may* result.

To determine whether this is the case inspect the "equilibrium polygon." If this *also closes* [*i. e.*, if S_0 and S_n intersect] the forces are in equilibrium. If this does *not* close [*i. e.*, if S_0 and S_n are *parallel*] there is no single resultant, but the forces can be replaced by a *couple*, and this couple, as we have seen, may have *any* position in the plane.

21. Thus if we suppose in Fig. 11, P_1 and P_2 decomposed into their components S_0, S_1, and S_1, S_2, the compressive strains in S_1 at *c* and *d* are equal and opposite [see (*a*)]. We have then S_0 and S_2 remaining which again form a couple which must have the same action as the first.

Hence we see that *one couple can be replaced by another without changing the action of the forces.*

It is easy to determine a simple relation between any two couples. If from *c* we lay off *c a* equal to *o* 1, and *c o* equal to C_0, we have *o a* parallel to C_1 or S_1, and therefore to *c d.* Join *a d* and *o d.* The triangles *c d a* and *c d o* having a common base *c d* and their vertices *o* and *a* in a line parallel to *c d*, are equal in area. The side *c a* of one is known, and the opposite apex lies in the line of the force P_2. Its area is then *c a* $= P_1$ multiplied by half of the perpendicular distance of P_1 from P_2, and is therefore completely determined. So also for the other triangle, one side of which *o c* is one force of the new couple, and the opposite apex of which lies in the other force S_2.

Hence—*a couple can be turned at will in its plane of action, and the intensity and direction of its forces can be changed at will if the area of the triangle the base of which is one of the new forces, and whose opposite apex lies in the other force, is constant; or when the product of the intensity of the forces into their perpendicular distance remains the same.* The direction of rotation, of course, must also remain the same.

FIG. 11. (a)

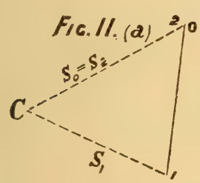
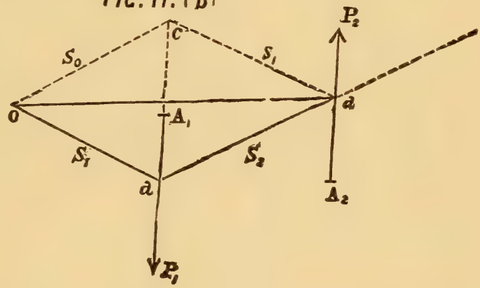
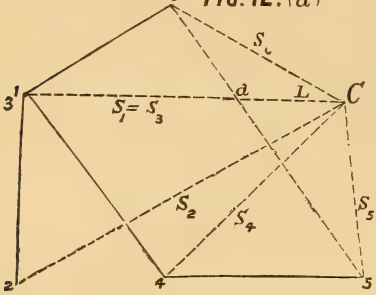


FIG. 11. (b)



We shall see further on the significance of this area, or of this product—so much is clear, that a couple (or infinitely small, infinitely distant force) is completely determined in its plane when the direction of rotation is given, and the

Fig. 12. (a)



area of the triangle or value of the product to which it is proportional, is known. The couple itself can be replaced by any two parallel equal and opposite forces whatever, if only the triangle having one force as base, and the

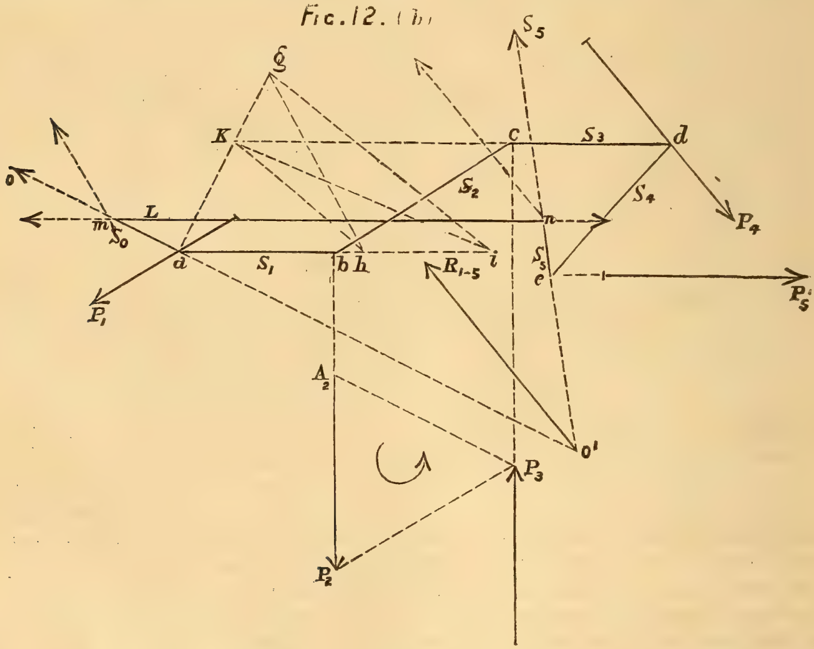
In Fig. 12 (b) we have the forces $P_{1\text{-}5}$ acting in various directions and at different points of application. P_2 and P_3 form a *couple;* that is, are equal, parallel, and opposite in direction. Required the position, intensity and direction of action of the resultant.

First, form the *force polygon*, Fig. 12 (a), by laying off the forces to scale one after the other in proper direction. Thus we have 0 1, 1 2, 2 3, 3 4, 4 5 in Fig. 12 (a) parallel respectively to P_1 P_2 P_3, etc., in Fig. 12 (b). The line necessary to close the polygon, 0 5, is the resultant in intensity and direction. In intensity because the length of 0 5 taken to the scale of force, gives the intensity of the resultant; in direction because acting from 5 to 0 it produces equilibrium, while acting in the opposite direction, from 0 to 5, it replaces the forces.

We have, therefore, only to find the *position* of the resultant in the plane of the given forces in Fig. 12 (b). Hence:

Second, choose a "*pole*" as C, and

Fig. 12. (b)



opposite apex in the other, has a given constant area.*

22. Force and Equilibrium Polygons for any Number of Forces in a Plane.

draw the line or rays, or "*strings*" S_0 S_1 S_2 S_3 S_4, etc. S_0 and S_5 are evidently components of the resultant, since they form with it a closed figure in the force polygon.

Third, form the *equilibrium polygon* $o\ a\ b\ c\ d\ e\ o'$, Fig. 12 (b), as follows:

***Elemente der Graphischen Statik.* Bauschinger. München. 1871. Pp. 11, 12.

Draw a line parallel to S_0 intersecting P_1 (produced if necessary) at any point as *a*. From this point draw a line parallel to S_1 to intersection with P_2 (also produced if necessary) at *b*. From *b* parallel to S_2 to *c*, then parallel to S_3 to *d*, and finally parallel to S_4, to intersection *e* with P_5. Through this last point draw a line parallel to the last ray S_5. Now S_0 and S_5 are components of the resultant 0 5 [Fig. 12 (*a*)] and are found in proper relative position. Produce them, therefore, to intersection 0′. Through this point the resultant must pass. Drawing them through 0′, a line parallel to 0 5, we have the resultant in proper position, and acting in the direction indicated in the figure, it produces *equilibrium.*

Any other point than *a*, upon the direction of P_1, assumed as a starting point, would have given a different point 0′; so also for any other assumed position of the *pole* C. But in every case we shall obtain a point upon the line of direction of $R_{1\text{-}5}$ already found. The reader may easily convince himself of this by making the construction for different poles, and points of beginning, and a little consideration will make the reason apparent.

Now the polygon or broken line, *a b c d e*, we call the *equilibrium polygon*—that is, *it is the position which a system of strings or struts, S_0 S_1 S_2, etc., would assume under the action of the given forces at the assumed points of application.*

Thus P_1 acting at *a*, is held in equilibrium by the forces along S_0 and S_1, P_2 acting at *b*, by S_1 and S_2 and so on. If we join any two points in the line of direction of S_0, and S_5, as *m n* by a line, we have then a *jointed frame*, which acted upon at the apices *a*. . .*e* by the forces P_1. . .P_5, and at *m* and *n* by S_0 and S_5 is *equilibrium.*

For S_0 acting at *m*, we see from the force polygon may be *replaced* by a force *a o* parallel and opposed to the resultant R and a force C *a* acting along the line L. In like manner S_5 may be *replaced* by *a* C and 5 *a* parallel and opposed to the resultant. The two forces *a* C and C *a* being equal and opposed balance each other through *m n*, while the sum of *a o* and 5 *a* is equal and opposed to the resultant 0 5. There is, therefore, equilibrium, and *m* and *n* may be considered as the *points of support* of the frame acted upon by the forces P_1 . . .P_5 at the apices *a*. . .*e*, *a o* and 5 *a* being the upward *reactions* at the points of support.

As to the *quality* of the strains in the different pieces, as before the reaction at *m*, viz., *a o*, is in equilibrium with the strain in *m n* and *m a*. Following round, then, in the force polygon from *a* to *o*, *o* to C and C to *a*, and referring back to the *frame*, we find strain in *m n* acting *towards* apex *m*, therefore *compressive;* strain in *m a* acting *away* from *m*, therefore *tensile.* In like manner S_1 S_2 S_3 are in tension, while S_4 or *d e* and S_5 or *e n* are compressed.

Hence we may *fix* any two points of the equilibrium polygon by joining them by a line. The forces acting at these points are at once found by drawing from C in the *force polygon* a parallel to this line to intersection with resultant. Thus *a* C (since we have taken *m n* parallel to S_1) is the force in *m n* and *a o*, 5 *a*, are the forces opposed to the resultant at *m* and *n*.

23. Influence of a Couple.—Among the forces in Fig. 12 there are two P_2 and P_3 which are equal, parallel and opposite, the direction of rotation being as indicated by the arrow. Examining the equilibrium polygon, we see that the influence of the couple is to *shift* S_1 *through a certain distance parallel to itself*, to S_1. Now suppose the forces composing the couple *were not given*, but the *value* of the couple known, from the direction of rotation and the area of the triangle A_2 P_2 P_3, which has its base equal to one of the forces and a height equal to their perpendicular distance. In this case the lines 1, 2 and S_2 in the *force polygon*, would disappear, but we can none the less find the point *d*, and from this point continue the polygon by drawing S_4 and S_5, and thus finding the same points *e* and 0′ as before. To do this we have simply to apply the principle deduced in Art. 21, that one couple *can be replaced by another provided the area of the triangle is constant.*

In the present case we must replace the given couple by another whose forces are S_1 and S_3, having the same direction of rotation.

Lay off then from *a*, *a i* equal by scale to S_1 as given in the *force polygon.* Describe upon S_1 the triangle *a g h* equal to the given area A_2 P_2 P_3. Draw *g i*, and then through *h*, *h k* parallel to *g i*.

The point K is upon the line of direction of S_3, or in other words the area of the triangle *i* K *a* is equal to *a g b*. The proof is easy. The two triangles *i g h* and *i g k* are equal, since they have the same base *i g*, and height. But if from the triangle *a i g* we subtract *i g h*, we obtain *a g h*. If from the *same* triangle *a i g* we subtract *i g k*, which is *equal* to *i g h*, we obtain *i* K *a*. Equals subtracted from equals leave equals. Hence *i* K *a* is equal to *a g h*.

If then through K we draw a line parallel to S_3 and produce it to *d*, we have the same point as before, and this from *d*, can continue the polygon.

[*Note* that the direction of rotation

Fig. 13. (a)

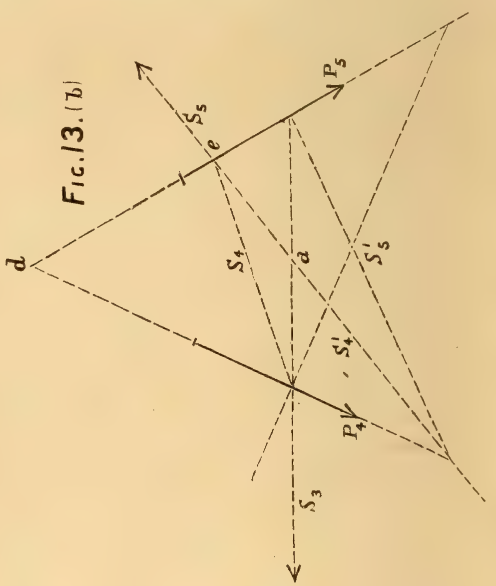


Fig. 13. (b)

shows the side of S_1 upon which the point g must fall. S_1 acts away from *a* [from 1 to C in (*a*)] hence for rotation as shown by the arrow *g* must fall above S_1, and S_1 is shifted *upwards.*]

24. Order of Forces Immaterial.—As in the case of a common point of application, so also here, the *order in which the forces are laid off is immaterial.* To prove this for two forces is sufficient, as by continued interchange of two and two, we can obtain any desired order.

Let the two forces be P_4 and P 5-1 existing either alone, or in combination with others preceding and following.

Taking the forces first in the order P_4 P_5, we have the *equilibrium polygon* S_3 S_4 S_5, giving the point *a* in the resultant. Taking them now in reverse order, P_5 P_4, we have the polygon S_3 S'_5 S'_4 giving the same point *a* in the resultant. The resultant in the force polygon (*a*), viz., 0 5, is of course unchanged in intensity and direction in either case. It is required to prove that in the second case the last string S'_4 is not only parallel to S_5 in the first, but *coincides with it.*

This is easy. The resultant of P_4 P_5 goes through *a*, the intersection of S_3 and S_5. The same resultant in the second case must also pass through the intersection of S_3 and S'_4. But S_3 is the same in position and direction in both cases. If the second point of intersection does not coincide with *a*, still it must lie somewhere upon S_3. Hence as the resultant must pass through both points, it must *coincide* with this last line; viz., S_3. But this is not possible, as the resultant must also pass through *d*, the point of intersection of the forces, or when these do not intersect must be parallel to them. As therefore S'_4 must be parallel to S_5 (shown by the force polygon), the intersections in each case must coincide, as also the lines S'_4, S_5 themselves, and the polygon from *e* on has the same course in either case.

25. Pole taken upon closing line.—We have seen (Art. 20) that when any number of forces are in equilibrium *both* the force and equilibrium polygon must

close. There is one exception to this statement. Since the pole may be taken anywhere, suppose it taken somewhere

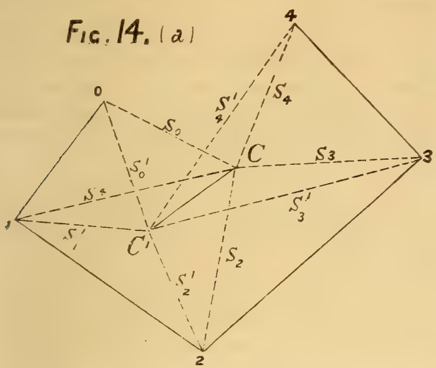


Fig. 14. (a)

upon the line closing the force polygon. This line, as we know, is the resultant, and holds the other forces in equilibrium.

equilibrium. If the equilibrium polygon however does not close, the forces cannot be replaced by a single force but only by a couple. The forces of this couple act in the parallel end lines of the equilibrium polygon, and are given in intensity and direction of action by the line from the pole to the beginning of the force polygon [beginning and end coinciding.]

26. Relation between two equilibrium polygons with different poles.—We may deduce an interesting relation between the two equilibrium polygons formed by choosing different poles, with the same forces and force polygon.

Thus with the forces P_1 P_2 P_3 P_4, we construct the force polygon Fig. 14 (*a*). Then choose a pole C and draw $S_{0\text{-}4}$, and thus obtain the corresponding equilibrium polygon S_0 *a b c d* S_4 Fig. 14 (*b*). Choose

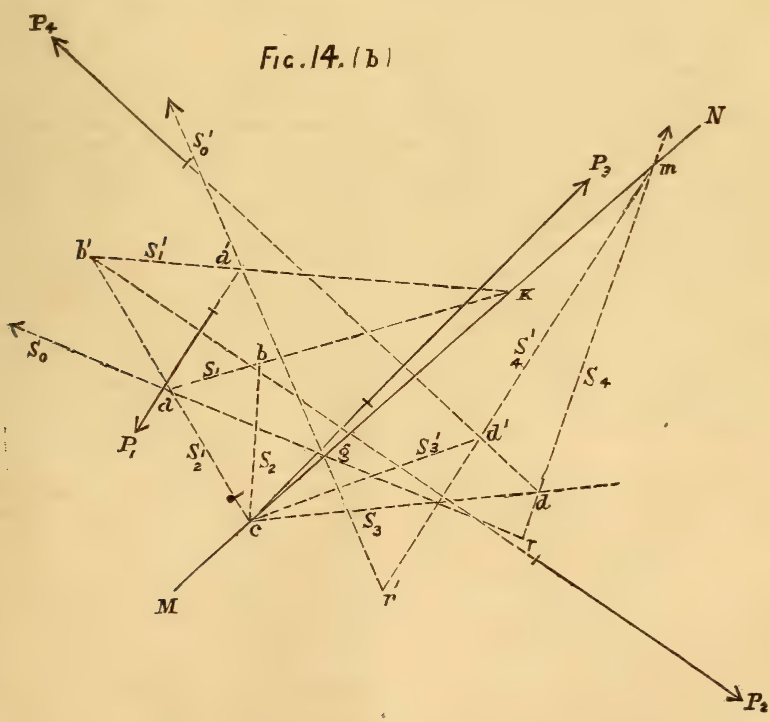


Fig. 14. (b)

But now the equilibrium polygon evidently *will not close.* On the contrary the first and last strings will be parallel. This position of the pole should then be avoided. For any other position of the pole our rule holds good; viz.,

If the force polygon closes as also the equilibrium polygon, the forces are in now a second pole C′. Draw $S'_{0\text{-}4}$ and construct the corresponding polygon S'_0 *a′ b′ c′ d′* S'_4. In our figure *c* and *c′* fall accidentally nearly together.]

Join the two poles by a line C C′. Then —*any two corresponding strings of these two polygons intersect upon the same straight line M N parallel to C C′.* Thus

S_0 and S'_0 intersect at g, S'_1 and S_1 at K, S'_2 and S_2 at c, S'_3 and S_3 at c', S'_4 and S_4 at m—and *all* these points g, k, c, c' and m, lie in the same straight line M N parallel to the line C C′ connecting the poles.

The proof is as follows.* If we decompose P_1 into the components S_0 S_1 and S'_0 S'_1, these components are given in intensity and direction by the corresponding lines in the force polygon. If we take the two first as acting in opposite directions from the two last, they hold these last in equilibrium. The resultant therefore of any two as S_0 and S'_0 must be equal and opposed to that of the remaining two, S_1 and S'_1, and both resultants must lie in the same straight line. This straight line must evidently be the line g k joining the intersections of S_0 S'_0 and S_1 S'_1. But from the force polygon we see at once that the resultant of S_0 and S'_0 is given in direction and intensity by C C′, and this is also the resultant of S_1 and S'_1. The line joining g and k must therefore be parallel to C C′. For the second force P_2 we can show similarly that the line joining k and c is parallel to C C′. But k is a common point of *both* lines—hence g k and c lie in the same straight line parallel to C C′.

[NOTE. *The pure geometric proof is as follows: The two complete quadrilaterals* 0 1 C′ C *and g k a′ a have five pairs of corresponding sides parallel*, viz., 0 1 *and a a′*, 1 C′ *and a′ k*, C 0 *and a g*, 0 C *and a′ g*, 1 C *and a k; hence the sixth pair are also parallel*, viz., C C′ and *g k*. *In like manner for* 1 2 C C′ *and c k b′ b and so on.*]

We can make use of this principle in order from one given equilibrium polygon S_0 a b c d S_4 and pole to construct another, the direction of C C′ being known. For this purpose, having assumed the position of the first string S'_0 we draw through its intersection g with S_0 a line M N parallel to C C′. The next string must therefore pass through the intersection a' of S'_0 and P_1 and through the point k, of intersection of the second string of the first polygon and the line M N. It is therefore determined. The next side must pass through b' and c, and so on.

[*Note.* Observe that the intersections r and r' of the first and last lines of both polygons must lie in a straight line parallel to 0 4, the direction of the resultant.]

Elemente der Graphischen Statik. Bauschinger. Pp. 18-19.

REPORTS OF ENGINEERING SOCIETIES.

THE American Society of Civil Engineers have devoted the time of their late meetings to the discussion of the City Rapid Transit Question. A complete list of their recent papers will be given in our next.

THE American Institute of Mining Engineers commenced their Winter Session on February 23.

AT a meeting of the American Iron and Steel Association, Mr. S. Z. Durfee read a valuable paper on the "Iron Trade and Transportation," an abstract of which we shall shortly reprint.

IRON AND STEEL NOTES.

SMOOTH AND BRILLIANT CASTINGS.—M. Collignon says that a saving of 80 per cent. is made by suppressing the sifted coal and charcoal used with green sand for small iron castings, by a careful mixture of one part of tar with twenty of green sand; the flashing by means of tar or resin is also suppressed by the same means. Castings produced from moulds with such a mixture are smooth and bright, because the tar prevents the metal adhering to the sand, and the formation of blisters. Such a mixture also aids greatly in the production of large castings, as the tar absorbs the humidity of the sand.—*Iron.*

IMPROVEMENTS IN PUDDLING.—M. Masian, of Louvroil, near Maubeuge, Nord, France, has patented in France and Belgium a new furnace. The form is nearly conical, the air being freely admitted through apertures made all along the face of the furnace at the height of the bars. The heat is made to concentrate itself in the sole of the furnace, accelerating the puddling. The puddler is exposed to much less heat than in the case of the square furnaces, and it is said to be able to make from eight to nine charges of good raw iron, No. 2, in twelve hours, with a consumption of 1,400 to 1,050 kilogs., an economy set down at 300 to 400 kilogs. of coal per ton of raw iron. The following are given as results of experience: With the Masian furnace, a ton of good No. 2 raw material was produced with 1,050 kilogs. of coal, the ordinary furnace requiring 1,300 kilogs. A ton of extra strong iron was produced in the new furnace with 1,252 kilogs. of coal, the old furnace consuming 1,502 kilogs.—*Iron.*

TEMPERING STEEL.—The Government of the United States has acquired, for the sum of 10,000 dollars, the following process, invented by MM. Garnant and Seigfield, for tempering steel: The steel, heated to a cherry red, is sprinkled with sea salt, and worked in this state until it has assumed nearly the form required, the chloride of sodium being renewed from time to time. For the latter is afterwards substituted a mixture of equal parts of chloride of sodium, sulphate of copper, sal-ammoniac, carbonate of soda, and a half-pint of saltpetre. The steel is again heated, and the hammering is continued until the steel becomes refined throughout its whole substance, and assumes the desired shape. It is then again brought slowly to a cherry-red heat, and plunged into a bath of 3.7 litres ($3\frac{1}{4}$ quarts) of rain water, 42.4 grammes (1.484 oz.) of alum, the same quantity of carbonate of soda and sulphate of copper, 28.3 grammes (1 oz.) of saltpetre, and 169.8 grammes (5.843 oz.) of chloride of sodium.—*Iron.*

Steel and Iron Making.—M. Willans announces improvements in the following terms: 1. During reheating or fusion, in order to prevent burning, he injects over or under the metal oil, creosote, oxide of carbon, hydrogen gas, or other carburetted or hydrogenous substance, in order that the oxygen present may combine with it instead of oxidizing the metal. 2. Reheating or softening of cast iron or steel, when not placed in a cold state in the presence of substances producing oxygen, by bringing them in contact, when nearly at a red heat, with carbonic acid gas, produced from limestone or other carbonates; or, vapors containing oxygen gas, such as steam or nitrous acid, may be used for the purpose. 3. Steel tubes of good quality may be produced by the employment of only soft steel, which is easy to draw, by annealing them when half formed, in the presence of iron ore or other oxidizing agents. The same observations are applied to the making of tubes from a mixture of steel and cast-iron.—*Iron.*

RAILWAY NOTES.

Preservation of Railway Sleepers.—A work has recently been published in France, entitled "A Treatise on the Preservation of Wood, Foods, and various Organized Matters," in which the author, M. Maxime Paulet, chemist, recommends for railway sleepers, pit props, and wood generally, the use of sulphate of copper and creosote.

M. Paulet says: So far as sulphate of copper is concerned, this salt is poisonous to the vegetable and animal parasites which appear at the beginning of all organic decomposition. The quantity of salts of copper should be excessive when the wood is intended to be immersed in water or buried in a moist soil, because the water dissolves this salt slowly; and since sea water enters into combination with it still more rapidly, it should be excluded from use for wood used in the sea. There is in wood impregnated with the salts of copper a portion of the sulphate closely united with the liqueous tissue and another portion in excess remaining free. This latter portion dissolves first, and, carried off by the exterior fluids, only retards the loss of the metallic salt combined with the wood; but this combination itself, although more stable, does not escape removal, being accelerated or retarded according to the rapidity and ease with which the dissolving liquid is renewed. On the contrary, the quantity of metallic salts should be diminished in wood intended for constructions in the open air, in order to prevent the mechanical effect of intra-vascular crystallizations.

As regards creosote oil, it is beyond doubt that the petroleum products containing phenic acid are preferable to the metallic salts for wood exposed to sea water, because naphthaline, and especially phenic acid, exercise an anti-septic action, coagulate the albumen, and thus obstruct the circulation of the sap or blood of parasites. The volatility and the solubility of these preservative agents would render their antiseptic action temporary only, if the more fixed and thicker oils which accompany them did not enclose and retain the preceding substances, at the same time obstructing all the pores of the wood, and rendering difficult the access of dissolving liquids and destructive gases. On the other hand, grave objections have been raised from a practical point of view, either because of the restricted production of these oils, which is not sufficient for a general use of them, or because the wood thus impregnated offers greater danger from fire, this wood once on fire being unextinguishable; that, on the contrary, sulphate of copper, like all the metallic salts, renders the wood uninflammable.

On the subject of the preservation of wood the *Polytechnisches Centralblatt* has lately remarked that in 1862 Messrs. J. and G. Leuchs advised the boiling of railroad ties in paraffine, or coating them with this substance; but this operation did not seem practicable to Mr. Hock. In order to effect impregnation it is necessary to fuse the paraffine, and vapor of petroleum seemed to him the dissolvent best suited for this purpose. The ties are introduced into an iron cylinder or reservoir, heated on the outside by a steam jacket. The wood, already as dry as possible, is raised to the highest degree of desiccation by the introduction of steam into the jacket, and when no more vapor escapes from it the solution of paraffine is introduced into the cylinder by means of a tube and compressed air. This cylinder has a refrigerating coil which discharges into a closed receiver. Then steam is let into the jacket again. The liquid waters boiling, and the vapor of petroleum gas not being able to escape, the pressure inside the cylinder rises, and is permitted to reach 75 to 100 lbs. per square inch; at this pressure the wood is completely impregnated with the liquid. When this action has been prolonged sufficiently, the heating is stopped and the operator waits until the pressure has fallen to a mininum, and the excess of paraffine is drawn off into the reservoir. Now, in order to collect also the dissolvent absorbed by the wood, it is again heated. When the remainder of the vapor of petroleum has been dissolved, air is blown into the cylinder in order to drive out the gases which might incommode the workmen who take out the wood.

The paraffine remains distributed minutely within the wood between the ligneous fibres, envelopes them, on melting, with a thin coating, and at the same time fills the pores and the cellular intervals. The wood is then guaranteed forever against moisture, while the dissolving of sulphate of copper, chloride of zinc, coal oil, etc., which have been recommended, are dissolved and carried off by water. Nails do not rust as in wood impregnated with metallic salts, and fragments of the preserved wood keep their value as fuel, while those of sulphated or zincked wood burn with difficulty.

Fatty Matter in Feed-water of Boilers.—It is known that a quantity of fatty matter in the feed-water of a boiler causes a deposit which is not wet by water, and that this may lead to destruction of the boiler, inasmuch as the part of boiler side under the incrustation becomes more heated than other parts, and is apt to occasion rupture. A case of this kind, observed by M.

Birnbaum, of Carlsruhe, has formed the subject of an investigation which he describes in a recent number of Dingler's *Polytechnisches Journal.*

The boiler in question had become leaky about two months after working had commenced, and most likely from a cause like that indicated, the incrusted boiler plates getting heated, and being bellied out by the steam pressure; when the boiler cooled, the metal sought to right itself, and thereby a force was developed sufficient to tear the rivet holes.

In the boiler there was found, besides a paper-thick coating of the usual deposit over the whole surface that was under water, a layer (from 2 to 3 mm. thick), of pulverulent matter, on the foremost half of the boiler bottom, which was a little inclined towards the fireplace. This powder was found very difficult to wet with water. Analysis showed that the incrustation contained a soap not soluble in water; there was at least six per cent. fatty acid present in the form of an insoluble soap. This fatty acid must have been neutralized by a certain quantity of lime or magnesia; and, to determine this, a quantitative analysis of the deposit was made. The result was: Matter insoluble in muriatic acid (mud, sand), 16.83 per cent.; oxide of iron, 10.68; lime, 29.28; magnesia, 9.01; carbonic acid, 21.78; organic matter, 9.47; water, 2.77; total, 99.82 per cent. There was also present a small quantity of sulphuric acid which could not be quantitatively determined. If we suppose the whole of the carbonic acid combined with lime, this will take 27.72 per cent of lime, so that 1.56 per cent. lime and 9.01 per cent. magnesia remain available for neutralization of the fatty acid (which is included in the organic matter in the above analysis). With the proviso that the fatty acid was mainly oelic acid, the 1.56 per cent. lime would more than suffice to neutralize the acid; a portion of the alkaline earths must thus have been free, perhaps in the form of a basic carbonate, in the deposit. It appeared, at all events, from this analysis that the powder contained at least 7 to 8 per cent. of an insoluble soap.

A further point to determine was whence the fat of this soap had come into the boiler. On examination it appeared that the spring water used for feeding the boiler was peculiarly adapted for this. The water, however, was previously heated in a heater, by waste steam entering it directly from the engine. Through the introduction of this steam the water was diluted, then distilled water was added, so that the water from the heater might give less deposit than the spring water. But in addition to the pure water condensed from the steam, other matters were introduced in the heater, which conduced to increase the precipitation of deposit. These were partly of an inorganic, partly of an organic nature. Among the inorganic matters must especially be mentioned hydrated oxide of iron. It could not but be that through action of air and carbonic acid of the spring water, the iron sides of the heater should have been covered with rust, which should afterwards be dissolved and transferred to the water. The iron rust was, however, only suspended in the water; filtered water of the heater contained no iron. The quantity of organic matters introduced into the water by the steam was not insignificant. These also are not soluble in water; filtered water of the heater contained a less quantity of organic matter than the spring water. The water out of the heater was directly examined for fat and soap, and out of 6 litres water .017 g. isolated fatty acid was obtained. With a still larger quantity the filtered water was quite free from soap, while the unfiltered showed a quantity of insoluble soap. Thus it appeared that the spring water, through contact with steam, took up fatty matter in the heater; this fat formed a soap insoluble in water, suspended in water along with hydrated oxide of iron. Volatile fatty acids—*e. g.*, butyric acid—which, in similar cases, have sometimes been found in feed water, were not observed by M. Birnbaum.

It follows as a practical result of this investigation, that the water in the heater should not be brought into direct contact with the waste steam. It is more rational to send the steam through pipes, over which the feed-water is made to pass. If the steam be sent direct into the water in the heater, the danger arising from presence of fatty matter may be so far diminished by filtration of the feed-water.

ENGINEERING STRUCTURES.

The Channel Tunnel.—The project of connecting England and France by a sub-marine tunnel is said to have been the subject of conversation between the Lord Mayor and the Minister of Public Works in Paris, and an arrangement is reported by the *Daily News* to have been come to between the governments of England and France, sanctioning preliminary experiments.

In 1872, the Channel Tunnel Company was incorporated; and Sir John Hawkshaw, Mr. James Brunlees, and M. Thomé de Gamond were appointed the engineers of the undertaking. Mr. W. Low, a gentleman much interested in the scheme previous to the formation of the company, has, we understand, now ceased to have any connection with it in an official capacity. The assent in principle of the governments of England and France has been obtained; but until the time arrives for constructing junctions with the railways terminating at Dover there will be no occasion to apply to Parliament. On the English coast, St. Margaret's Bay, a depression in the chalk cliffs, about four miles east of Dover, has been selected as the point of departure; and on the French side, a spot about midway between Calais and the village of Sangatte, has been fixed upon. By adopting this line, it appears from observations which have been made by Sir John Hawkshaw, that the tunnel can be almost wholly excavated in the lower bed of homogeneous chalk; and this stratum is upwards of 500 feet deep on each shore from high-water mark. It is believed, on apparently good grounds, that the chalk is continuous, and that it stretches beneath the sea uninterruptedly across the Straits. The maximum depth of water on the line of the proposed tunnel nowhere exceeds 180 feet below high-water mark, the water being deepest in the centre, and gradually diminishing in depth towards the sides. The tunnel itself would be placed by the engineers at such a level that the depth of strata over it would never be less than 200 feet; and this depth, which is amply sufficient for security, would permit the railway approaches to be formed with tolerably easy gradients. It has been ascertained by actual experiment that, provided the chalk be solid, the water will not permeate it; and it has also been shown on more than one occasion that comparatively little subterranean water exists in that formation. But the best possibility of tunnelling beneath the sea level is to be found at Brighton. Sir John Hawkshaw has there completed a tunnel 5¼ miles in length along the sea shore, and in close proximity to the margin of the sea. This tunnel is wholly in the upper chalk, where the material is not very compact; and it is 12 feet at one end, and 20 feet at the other end below high-water mark. Considerable quantities of water, chiefly fresh, were encountered in the progress of the work, and as much as 10,000 gals. per minute had sometimes to be pumped out; but the works were not prevented from proceeding. As pumping power ten times the magnitude of that employed at Brighton could, if necessary, be applied, the entry of small quantities of water during the construction of the Channel tunnel would not be in the least dangerous. Nothing, probably, could hinder the completion of the work but the existence of open, unfilled fissures reaching from the sea to a depth of at least 200 feet. It is believed that such fissures, if at any time existing, will be found to have been filled up in the lapse of ages.

With regard to the means by which it is proposed to execute the work, we should mention that tunnelling machinery has lately been invented by Mr. Dickenson Brunton (see *Iron*, Vol. III., p. 364, where the Channel tunnel is fully discussed) which has been practically and successfully tried in the lower chalk. The machine works like an auger, and the debris excavated falls upon an endless band which carries it to the wagons in the rear. By this means a driftway of 7 feet in diameter can be advanced at the rate of from a yard to a yard and a quarter per hour, and at this rate it would only require two years to pierce a way of 7 or 9 feet in diameter from one side of the Channel to the other, a machine being worked from each side. The engineers' estimates of time and cost for the preliminary works are four years and £1,600,000 respectively; but experienced contractors think that only half the time and money would be required. It has also been computed that after the driftway is finished, four years' time and £4,000,000 would complete the entire work. We are assured that the ventilation of the tunnel, both before and after completion, would present no great difficulties. As the work advanced, pneumatic tubes might be laid down, which would not only aid ventilation, but which would also carry in and bring out the workmen, and remove the excavated chalk. When the tunnel is finished, it is expected that engines of 150 horse-power in the aggregate will provide sufficient permanent ventilation. The railway once completed, we suppose that few people will be found to deny its utility.

PROPOSED MONT BLANC TUNNEL.—It seems that the French Government is not now disposed to subsidize the railway which was formerly one of the cherished projects of the Empire, and was distinguished by the name of *La Ligne d'Italie.* This line was to have been carried through the Simplon, and some considerable progress had already been made with it on both sides of the Alps when the Franco-German war caused an interruption of the works, the result of which was that the Swiss Government declared the concession which had been made to a French company to be forfeited, and then took possession of the plans and material, as well as of the line itself. Against this act the French Government remonstrated, but as the line nowhere touches French territory, it does not now seem likely to receive any pecuniary assistance from that quarter. The failure of this enterprise has given rise to a project for constructing a railway through the Alps which shall connect the frontiers of France, Italy, and Switzerland; and the French journal, *Le Constructeur*, gives the details of a survey lately made with this view by M. Ernest Stamm, a French engineer, assisted by Signor Léon Maimeri, who, after carefully inspecting and surveying the district for two consecutive years, ascertained that a section of Mont Blanc taken at an altitude of 1,300 metres, presents a base of only 11½ kilometres, and that a line of railway starting from Chamounix and tapping the mountain at or near Les Houches, would not present engineering difficulties so great as have already been surmounted at Mont Cenis, or are now being overcome at St. Gothard, and it would, moreover, prove much more advantageous to France as a commercial line than that by the Simplon, as well as offer the greatest attraction to tourists.

ORDNANCE AND NAVAL.

THE FOG GUN.—For some time past endeavors have been made to secure for coast-signal purposes something more suited to the duty than the 18-pounder cast-iron gun now used. Major Maitland, R. A., of the Royal Gun Factory, has designed a species of revolving gun which will no doubt answer the purpose admirably. But in order to determine the best material and form of muzzle for the new fog gun, four models, each 2 feet long and capable of containing a cartridge consisting of from four to five ounces of powder, were constructed upon the following different plans, to be tested from the summit of the proof butts in the Plumstead marshes, at various respective distances: A cast-iron gun with a plain muzzle; a cast-iron gun with a conical mouth; a cast-iron gun with a parabolic mouth; and a bronze gun with a parabolic mouth. The object of trying both conical and parabolic mouths was to arrive at a decision in regard to the question which has always been pending among manufacturers of speaking-trumpets, as to which is the best shape for transmitting sound. Some assert that the form of the instrument should be a truncated cone; others, that it should be a truncated parabolic canoid, the mouth-piece occupying the focus. Either form would, in a greater or less degree, confine the undulations of sound (which would otherwise disperse themselves in all directions) and cause them to take a direction parallel to the axis. Hence the application of one or the other of them. On the occasion of the recent experiments the four models were placed in a row upon the summit of the butts, with their muzzles pointing towards Shooter's Hill. The weather was cold and clear. The observers stationed themselves at various distances in front of the row of guns, from 100 to 3,000 hundred yards, moving forward to a greater distance each time that the whole series of four guns was fired. They were ignorant of the order in which the guns were fired, that being purposely left in the hands of the proof master, so it was impossible for their opinions to be prejudiced. It was decided that the volume of sound emitted by each discharge should be presented as nearly as possible in figures, No. 1 being the "highest" figure of merit, and No. 5 the lowest. The following results were obtained: Adding together the respective figures of merit of each gun at eight several distances from 100 to

3,000 yards, it was found that the cast-iron gun with the conical mouth gave a total of 10, or in other words took the first place as regards the volume of sound produced at all ranges; the cast-iron gun with the parabolic mouth a total of 21, thus taking the second place; the bronze gun with the parabolic mouth a total of 22½, or taking the third place; while the cast-iron gun with the plain or straight mouth gave 26½, the lowest value of all four. At a distance of a thousand yards only, the bronze gun with the parabolic mouth took the second place. This was probably due to the superior ringing qualities of the metal, which would be observed at such a short range. Further experiments were then made by observers stationed about two miles off upon Shooter's Hill. The figures of merit under these circumstances for the several guns were as follows: Out of six observations, 6 for the cast-iron cone, 12½ for the cast-iron parabola, 19 for the bronze parabola, and 22½ for the cast-iron plain mouth. Thus we see that the great increase of distances is very unfavorable to the bronze model, and that the plain muzzled one is out of the field altogether.

During the above-mentioned experiments trials were made with gun-cotton, in order to see whether the sound of its report on explosion would reach to any great distance. Masses consisting of about ten ounces were detonated in the open air upon the butts. The noise made considerably exceeded that of the guns. It must be remembered, at the same time, that the proportion of powder in the gun-cartridges bore no analogy to the quantity of gun-cotton detonated. The result of the trials was, however, considered so satisfactory that a parabolic reflector is being constructed in which it is intended to explode pieces of gun-cotton.—*The Engineer.*

BOOK NOTICES

A Practical Treatise on the Gases Met with in Coal Mines. By J. J. Atkinson. New York: D. Van Nostrand. Price 50c.

This is No. 13 of Van Nostrand's Science Series, and is reprinted from the Magazine.

The original essay was prepared for the Manchester Geological Society (Eng.), and was published there to meet a wide demand.

The author, now deceased, was then Government Inspector of Mines.

Ceramic Art: A Report on Pottery, Porcelain, Tiles, Terra Cotta, and Brick. By Wm. P. Blake. New York: D. Van Nostrand. $2.00.

This is a volume of 140 pages. It is from the Reports of the Massachusetts Commission to Vienna.

The separate sections are devoted respectively to: General Survey; Porcelain and Faience; Floor, Wall, and Ornamental Tiles; Terra Cotta and Brick; Materials for Pottery.

A chart exhibiting the Monograms on Porcelain and Faience closes the report.

Many good illustrations are scattered through the text.

Chemical Examination of Alcoholic Liquors. By Albert B. Prescott, M. D. New York: D. Van Nostrand. Price $1.50.

The judgment of those whose opinions are of most value, has already been expressed in regard to the merits of this new work from the accomplished author of "Proximate Organic Analysis." The opinion was based upon the conspicuous merits of the above-mentioned work, and was unqualifiedly favorable.

The present work is designed as a manual of the constituents of the distilled spirits and fermented liquors of commerce, and their qualitative and quantitative determination.

"It has been shaped by the design, firstly as a necessary basis for analysis, to place in outline the chemistry of alcoholic liquors, including their current impurities and adulterations, in such terms as to be understood by persons having only an ordinary acquaintance with chemical science. Secondly, to furnish directions, so far as possible, for an efficient chemical examination, not more elaborate than required for commercial, hygienic, and legal purposes, and containing all details except such as are found in the first books of chemical analysis."

The book is nearly the size of "Proximate Analysis," and will supply a want more widely felt than that which rendered the first work so acceptable.

The Earth a Great Magnet. By A. M. Mayer, Ph. D. New York: D. Van Nostrand. 50c.

This is only an old acquaintance in a more fitting dress. In flexible cloth cover and with wider margins to the pages, it presents a far more satisfactory appearance than it formerly did.

The demand for this excellent essay is quite steady, and deservedly so, for from no other source can the student obtain so much accurate knowledge of terrestrial magnetism in so compact and readable shape. The change in outside fittings above referred to is coincident with the recent change in ownership of the "University Series" to which the book belongs.

Scientific Addresses. By John Tyndall, L.L.D., F. R. S. New York: D. Van Nostrand. 50c.

This formed No. 5 of the University Series, formerly published by C. C. Chatfield & Co. It now appears in neat flexible cloth cover, and is in every sense in appropriate dress.

Professional Papers of the Corps of Royal Engineers. Woolwich: Jackson & Sons. Price $8. For sale by D. Van Nostrand.

Volume 22 of the new series is at hand, and as usual the volume contains much that interests the profession at large.

Among other papers (there are thirteen in all) we notice: Our present Knowledge of Building Materials, and how to improve it; Experiments on the holding power of Earth, and the strength of Materials; The recent History of Explosive Agents; Notes on Portland Cement, and the Description of the Operation of Straightening a Brick Chimney Shaft at Woolwich.

The illustrations are for the most part excellent. A few poor heliotypes do not essentially mar the appearance of the book.

Principles of Metal Mining. By J. H. Collins, F. G. S. Lond. and Glasgow: Wm. Collins, Sons & Co. For sale by D. Van Nostrand. 75c.

This is another of the Collins Series, and affords an outline rudimentary in character of methods and tools employed in mining. It is rather meagre as a source of information to a student, but perhaps is sufficient for a general reader who is short of time.

ELEMENTS OF MAGNETISM AND ELECTRICITY. By JOHN ANGELL. London: Wm. Collins, Sons & Co. For sale by D. Van Nostrand. Price 75c.

This is an important addition to Collins's Elementary Science Series. It is compact, well illustrated, and affords valuable hints to experimenters as to construction and use of apparatus. It is illustrated with 120 wood cuts.

THE MICROSCOPE AND ITS REVELATIONS. By WM. B. CARPENTER, M. D. Fifth Edition. For sale by D. Van Nostrand. Price $5.50.

This is a new edition of an old and well-known book. Its reputation for general excellence is as wide as the use of the microscope among English readers. The present edition contains 25 plates and 449 wood engravings.

NOTES AND QUERIES ON ANTHROPOLOGY. By a Committee of the British Association. London: Edward Stanford.

This little work is designed as a guide to travellers and residents in uncivilized lands, pointing the way by which their observations may advance the science of Anthropology. There are one hundred sections or chapters, by a large number of scientists; each section giving a complete list of questions on a special subject, the answers to which are solicited from any who hold intercourse with barbarous peoples in any part of the globe.

To the general reader the book is of value, inasmuch as it indicates the line of study of the workers in this field.

THE ORIGIN OF CREATION, OR THE SCIENCE OF MATTER AND FORCE. By T. R. FRASER, M. D., and ANDREW DEWAR. London: Longmans, Green & Dyer. For sale by D. Van Nostrand. $4.

The title of this work is, to say the least, ambitious, and the first lines of the preface are not inconsistent with the character assumed by the title page. They run thus: "Unknown to the world of science, we present ourselves as advocates of the vast undertaking, which is we expect to revolutionize the whole theory of Natural Science taught and believed in at the present day, and to—" etc., etc. This is sufficient, we trust, to satisfy our readers that this span of authors make in no place an obtrusive exhibition of modesty. There are 234 pages of the effusion, but in brief scanning we could not find one of information.

AIR AS FUEL. By OWEN C. D. ROSS, C. E. London: E. & F. N. Spon. 1874. For sale by D. Van Nostrand. Price $1.50.

This is a compact and well arranged little work, not too diffuse, but containing much useful information. Though devoted to the support of what the majority would designate as a crotchet, viz., the sufficiency of oil-saturated air as a substitute for coal and coal-gas, it is far from devoid of value as a contribution to the already voluminous literature of fuel. It is to be regretted, however, that the author should not have given a sketch of the history of the many attempts that have been made to introduce the use of oil-gas, some of which have met with partial success. An analysis of the causes of failure would be highly instructive; and, till this has been done, the career of the Air Gas and the New Gas Companies, with other kindred undertakings, has been such as to discourage further attempts in the same direction, till there is some assurance of a palpable advance having been attained on the *modus operandi* hitherto adopted. The recent unprecedented fall in the price of petroleum, occurring simultaneously with the development of the oil-grounds of Asia, is, as Mr. Ross rightly points out, an important element in the matter. The latter half of the book, treating of carburetted air as an illuminating gas, though exhibiting somewhat of the sanguine spirit of the inventor, states fairly the grounds on which an opinion as to the chance of success of the new proposal may be formed.—*Iron.*

CATECHISM OF THE LOCOMOTIVE. By M. N. FORNEY, Mechanical Engineer. New York: Railroad Gazette. For sale by D. Van Nostrand. $2.50.

This book, which has been published in weekly parts in the *Railroad Gazette* during the first nine months of 1874, is now ready in book form. It treats, in 550 questions and answers, of the following subjects:

Part 1. The Steam Engine.
2. The Forces of Air and Steam.
3. On Work, Energy, and the Mechanical Equivalent of Heat.
4. The Slide-Valve.
5. The Expansion of Steam.
6. General Description of a Locomotive Engine.
7. The Locomotive Boiler.
8. The Boiler Attachments.
9. The Throttle-Valve and Steam Pipes.
10. The Cylinders, Pistons, Guide-Rods, and Connecting Rods.
11. The Valve-Gear.
12. The Running-Gear.
13. Adhesion and Traction.
14. Internal Disturbing Forces in the Locomotive.
15. Miscellaneous.
16. Screw Threads, Bolts, and Nuts.
17. Tenders.
18. Friction and Lubrication.
19. Combustion.
20. The Resistance of Trains.
21. Proportions of Locomotives.
22. Different Kinds of Locomotives.
23. Continuous Train Brakes.
24. Performance and cost of Operating Locomotives.
25. Water-Tanks and Turn-Tables.
26. Inspection of Locomotives.
27. Running Locomotives.
28. Accidents to Locomotives.
29. Accidents and Injuries to Persons.
30. Responsibility and Qualification of Locomotive Runners.

The book is illustrated with 250 wood engravings, nearly all from original drawings.

The talented editor of the *Gazette* has exhibited in this work remarkable power as an instructor. The expositions of principles are clear, concise, and yet full. The book has no competitor in the market, and we trust it will be found to be indispensable to every student of Mechanical Engineering who can read English.

A MANUAL OF TELEGRAPH CONSTRUCTION. By JOHN CHRISTIE DOUGLAS. London: Charles Griffin & Co. For sale by D. Van Nostrand. $7.50.

The telegraph engineer must be familiar to some extent with the practical duties for which the civil engineer is specially prepared. He must be familiar with the principles of framing, of determining the strains in struts and ties of complex trusses; with the general principles governing earthworks, whether in relation to retaining walls or foundations, and also with the methods of constructing good masonry. To be sure he is rarely called upon to apply these principles on an extensive scale, but a due regard to economy and durability requires a sound knowledge of the rudiments at least of these departments of civil engineering.

The author of the work before us begins his treatise with a comprehensive outline of Physics and Mechanics. The work is carefully done, and is worthy the attention of writers of more pretentious works of engineering.

The remaining sections treat in minute detail of the duties of the line builder, and the devices by which he overcomes obstacles of all possible kinds. Everything which is likely to demand the engineer's attention in his field work seems to have been considered, even to camp equipage and choice of camping ground.

The work contains 420 closely printed pages, and is abundantly illustrated.

Economic Geology; or, Geology in its Relations to the Arts and Manufactures. By David Page, L. L. D., F. G. S., &c. William Blackwood & Sons. Price $3.75.

It is to the credit of Mr. Page that in the volume which has given rise to these remarks, or rather in those chapters which refer to architecture and engineering, he has not followed the method of treatment usual with writers on geology, but has regarded stones from a practical standpoint. He has brought together a large quantity of information on the ordinary building stones, and on stones for decoration and sculpture, and for limes, cements, concretes, etc. The employment of stone in road-making, construction of railways, canals, docks, etc., is also treated. By confining himself principally to the stone found in England, and by good arrangement and concise expression, the chapters on architecture and engineering contain the pith of all that is known on the subject. The book, however, is intended for a wide circle of readers, as it treats in a similar style of geology in its relations to agriculture, land valuation, mining, pottery, medicine, metallurgy, etc. It can be recommended as a companion to all treatises on geology. A geological map, on a small scale, but comprehensive enough, accompanies the volume.

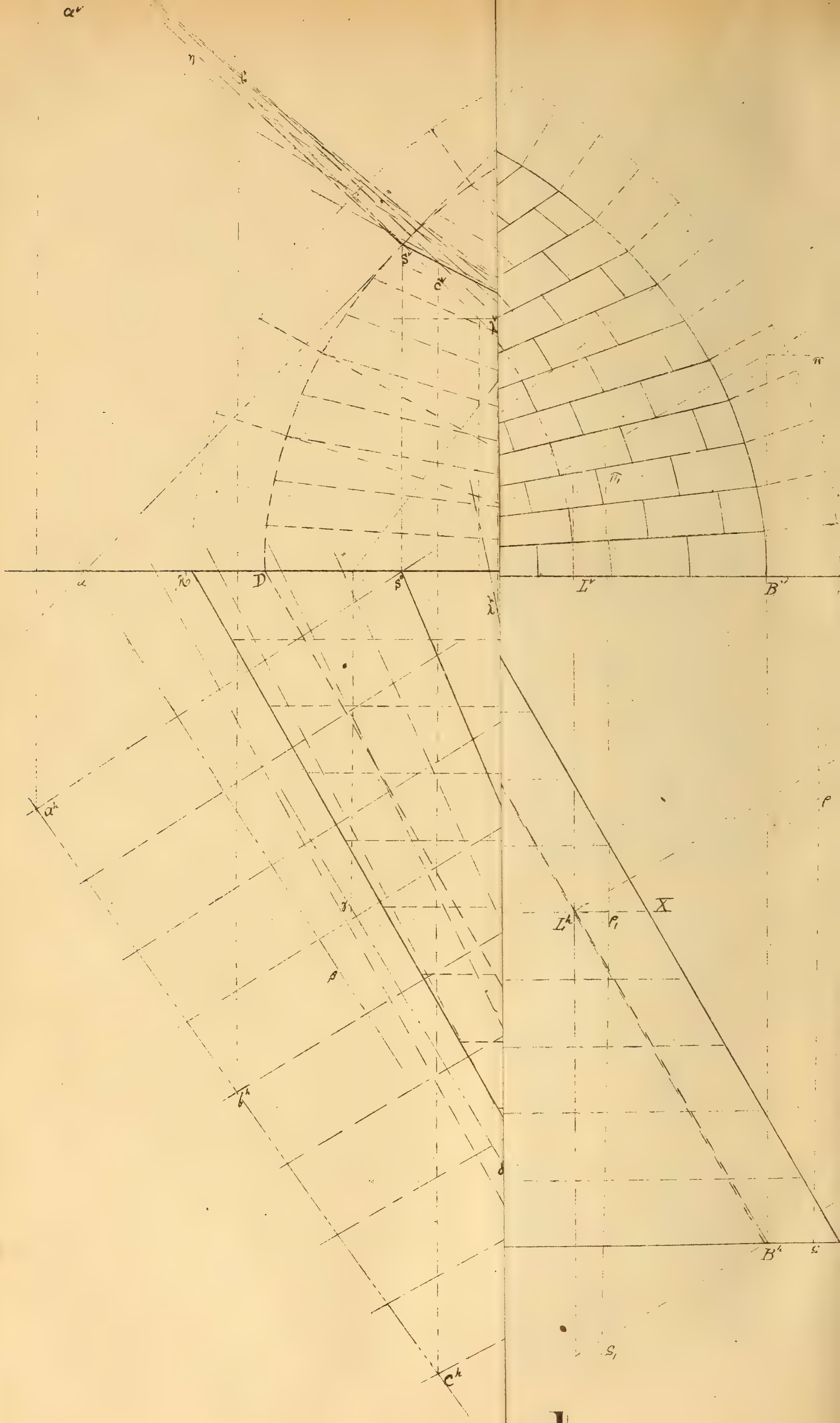
MISCELLANEOUS.

A New Enamelling Process.—The uses of enamelled plates during recent years have widely extended, and with the gradually accumulating improvements in the process of enamelling, will doubtless continue to extend. Their durability recommends them for all purposes where permanency is a desideratum, such as advertisements on walls, street names, and a hundred and one appliances in civilized life. For some years now a company has been working a patented process of enamelling plates of metal—sheet iron or copper generally—with lettering or designs suitable for various purposes, and for some time efforts have been made to reduce the cost of the process or to invent a new and cheaper one. If we may believe the patentee, Mr. J. H. Robinson, of Liverpool, has recently invented a process which is not only cheaper, but in which the resulting product is free from those specks of dirt which seem inseparable from the present methods of manufacture. The new process yields enamel of sufficient purity for dials and similar work, and is not so expensive as to virtually prohibit its use for ordinary purposes, such as name plates, notice boards, and wall advertisements. Thin sheet-iron is first cut and stamped to the desired shape, the edges of the plate being turned up slightly in the usual way so as to form a shallow tray, the edge serving to hold the enamel in position during the preliminary stages of the process. The plate is then to be made chemically clean by any of the ordinary processes of pickling and scouring. The ingredients of the enamel should be taken in the following proportions, but in some cases, or for certain purposes, they may be slightly varied: White lead, 12 oz.; arsenic, $2\frac{1}{2}$ oz.; flint glass, 8 oz.; saltpetre, 3 oz.; borax, $6\frac{3}{4}$ oz.; and ground flint, 2 oz. These are to be powdered and mixed thoroughly, placed in the crucible and fused; but before they are cooled they must be plunged into cold water, which has the effect of rendering the mass very brittle. The cakes of fused enamel are then pounded to about the fineness of coarse sand, washed and dried. The powder is then ready for use. The plates of sheet iron having been well cleansed and thoroughly dried, are sprinkled over with sufficient enamel powder to make the coating of the desired thickness, and are then placed in a muffle, the turned up edges retaining the swelling enamel in position. Lettering or designs can be produced on the surface by the ordinary means; but if it is desired to put them on when the enamelled plate is cold, they are first received on paper, an impression being taken on soft black enamel from the engraved plate, and subsequently transferred, the article being again placed on the muffle to fuse the enamel of the design or letters. The inventor claims that the iron back is more durable than copper, and it certainly is cheaper. Variations in the color of the enamel can of course be obtained by the addition of various salts and earths, such as those of cobalt, peroxide of manganese, protoxide of iron, etc., and similar diversity of color can be introduced into the design or the letters.—*Eng. Mech.*

The subject of underground temperatures at the British Association was treated in a report by Professor Everett, in which it is pointed out that the average result thus far is that the temperature increased at the rate of 1 deg. Fahr. in every 50 feet or 60 feet in depth. A very valuable set of observations has been received from a mine 1,900 feet deep in Prague, Bohemia. The depths and corresponding temperatures are as follows:

Feet.	Deg. Fahr.	Feet.	Deg. Fahr.
68	47.9	1,290	58.3
299	48.8	1,414	59.4
621	50.7	1,652	61.2
939	57.8	1,900	61.4

Iron or steel wire which has been acted on superficially by sulphuric acid is usually found to be altered in its properties. Its weight is increased, its tenacity is injured, so that originally soft and flexible, it easily breaks; and when a freshly-broken end is moistened by the tongue, it effervesces as if acted on by a mineral acid. These effects after a time disappear. Professor Osborne Reynolds, of Manchester, has ascertained that they are owing to the absorption of hydrogen generated during the chemical reaction which takes place when the wire is immersed in the acid.



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VAN NOSTRAND'S
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SKEW ARCHES.

COW'S HORN METHOD.

III.

BY E. W. HYDE, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

In this method the soffit is a warped surface called the *Corne de Vache*, or Cow's Horn, generated in the following manner. A right line moves on three directrices, which are: 1st, two equal ellipses in parallel, vertical planes, having their transverse axes in the springing plane of the arch; and 2d, a right line drawn in the springing plane perpendicular to the plane of the ellipses, through the centre of the parallelogram formed by joining the extremities of the transverse axes of the ellipses. These ellipses may, of course, as a particular case, be circles. In Fig. 3, the plane of one face of the arch is taken as the V P, and the springing plane is the H P. In referring to Fig. 3, the following notation will be employed. Any letter with *h* written above it as an exponent, means the *horizontal* projection of a point, and the same letter, with exponent *v*, is the *vertical* projection of the same point, and this point will be referred to as the point A, B, etc.; *i.e.*, the point whose projections are A^h A^v, B^h B^v, etc. A line drawn through these two points would be, therefore, the line A B. If one projection of a point is in the ground line, *h* or *v*, as the case may be, is replaced by *o*, and if the point itself is in the ground line, it will be designated by the letter alone without exponent.

In Fig. 3, the parallelogram A^h B^h C D is the horizontal projection of the soffit. Its centre O is the point through which the rectilinear directrix of the soffit is drawn perpendicular to the V P, since this coincides with a P F. The three directrices of the cow's horn surface are then the ellipses D S I C, and A K N B, and the right line O Z lying in the H P. The elements of the surface are to be drawn so as to cut these three directrices. The vertical projection of O Z is a point in the ground line at O^o, hence the vertical projections of the elements will be lines radiating from this point. By dropping perpendiculars from the points where the vertical projections of the elements meet the vertical projections of the elliptical directrices to the horizontal projections of the same, the horizontal projections of the elements will be found, as will be seen in the case of the elements R S, P Q, etc. *The elements of the surface are the edges of the voussoirs*—that is, the c j c's, which, therefore, in this method become right lines, while the h j c's, being sections of the soffit parallel to the P F, are curves of the 4th degree. It is, of course, impossible to *develop* the soffit, since the consecutive elements are not in the same plane.

The arch must be divided up into courses on the *median section* in order

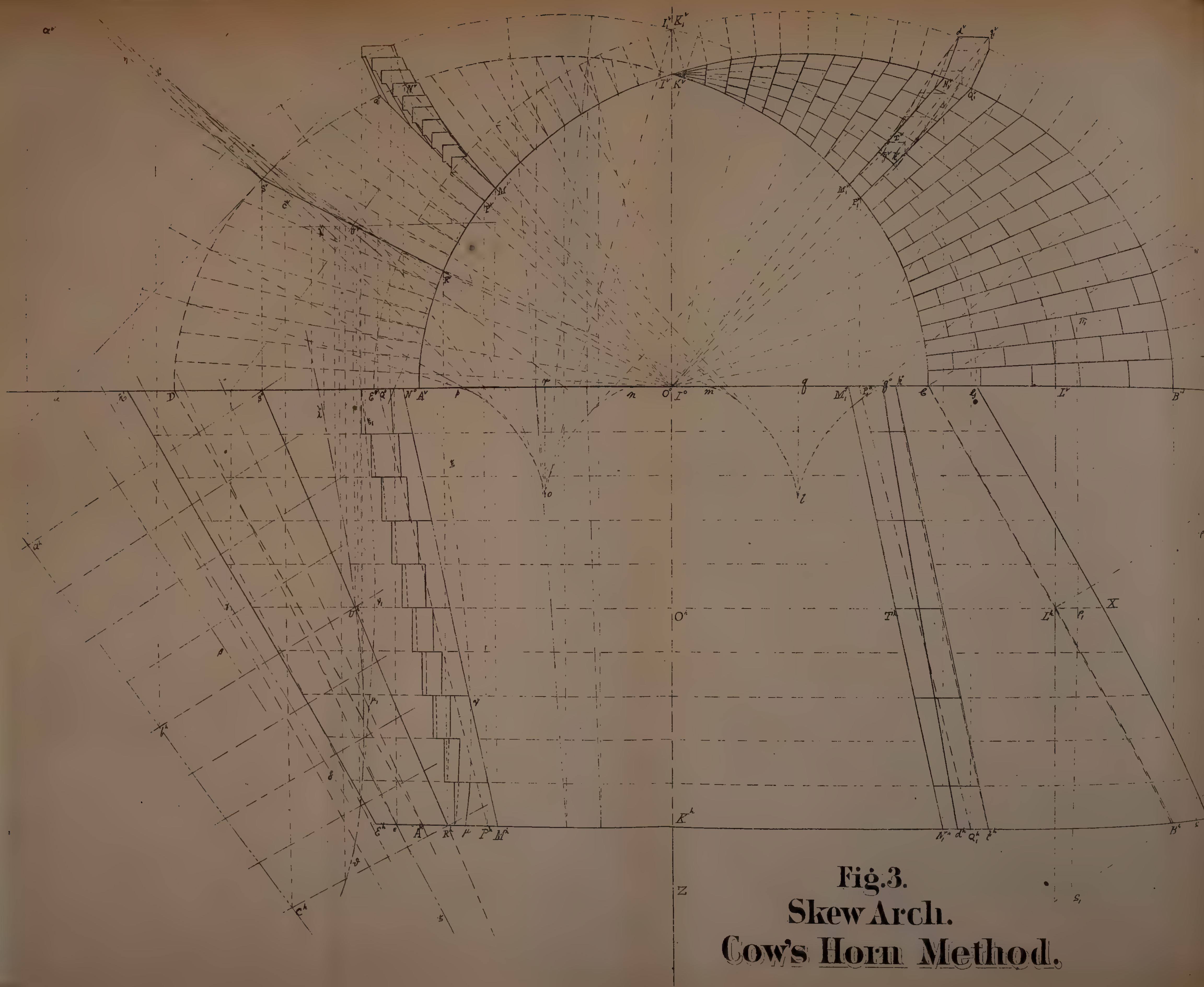
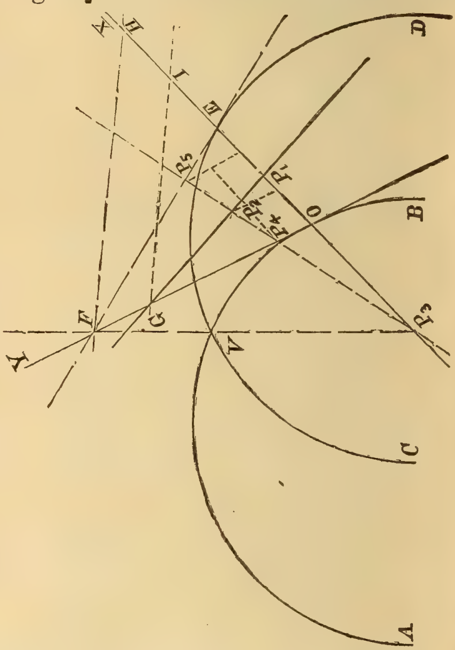


Fig. 3.
Skew Arch.
Cow's Horn Method.

that the two faces may be alike. To find this, draw the vertical projections of a number of elements, and bisect the portion of each included between the points in which it cuts the vertical projections of the elliptical directrices; through these points of bisection the median curve may be drawn. In Fig. 3, it is the line L T, and is only drawn as far as the crown of the arch. The length of this median curve would have to be ascertained by construction upon a large scale, and accurate measurement. It may then be divided into a convenient odd number of equal parts, and the elements of the surface, which are the c j c's drawn through the points of division.

The h j s's in this method, are planes parallel to the planes of the faces of the arch, while the c j s's are hyperbolic paraboloids the method of whose construction will next be shown. It will first be shown that a hyperbolic paraboloid may be drawn having an element in common with any warped surface, and normal to this surface at every point of the common element. It is proved in works on descriptive geometry, that, if two warped surfaces have a common element, and have common tangent planes at three different points of this element, they are tangent to each other throughout the length of this element. Therefore, we can always draw a hyperbolic paraboloid *tangent* to a warped surface along an element; for draw tangent planes at three points of any element, and in these planes, through the points of tangency, draw right lines parallel to some given plane; if a rectilinear generatrix be moved on these lines, a hyperbolic paraboloid will be generated tangent to the warped surface along the element. Now, revolve this tangent surface about the common element as an axis through an angle of 90°; it will then be normal to the other surface at every point of the element. If the lines drawn in the tangent planes are *perpendicular* to the common element, after revolution through 90°, they will be perpendicular to the tangent planes, and hence normals to the warped surface. Hence it follows that the directrices for a c j s may be three normals to the soffit, drawn at any convenient points of the corresponding c j c, or element. The points at which normals are most easily constructed are those in which the element cuts the three directrices, but as the intersection with the rectilinear directrix will generally be beyond the limits of the drawing, some other point must be used instead of this one. A method will now be given by which a tangent line can be easily and simply constructed at any point of any section of the cow's horn surface, by a plane parallel to the elliptical directrices. This tangent line being found, of course the normal to the surface at the point of tangency can be drawn at once. Let



A V B and C V D be vertical projections of the elliptical directrices, P_3 that of the rectilinear directrix, P_3 X that of the element through P_1, which is a point of some section of the soffit by a plane parallel to the P F, and O F and E F tangents to the curves A V B and C V D, at the points where they are cut by P_3 X. E F and O F will meet on P_3 F because this is the axis radical of the two curves.

Let O E $= a$, O F $= b$, P_3 O $= a_1$ and O $P_4 = b_1$. Take O as the origin of coordinates, the line P_3 X as the axis of abscissas, and the line O Y as the axis of ordinates. Then the equation of the tangent line E F will be

$$(72) \qquad \frac{x}{a} + \frac{y}{b} = 1;$$

that of the line P_3 P_5,

(73) $\frac{x}{-a_1}+\frac{y}{b_1}=1;$

and that of the tangent line O F,

(74) $x=0.$

We will now find the equation of the line cutting O X and $P_3 P_5$ in such a manner that $\frac{O P_1}{P_1 E}=\frac{P_4 P_2}{P_2 P_5}$. Let $O P_1 = n \times OE = n a$. To find the co-ordinates of the point P_5 eliminate between (72) and (73)

$$\therefore\ y_5 = b - \frac{b}{a} x_5 = b_1 + \frac{b_1}{a_1} x_5$$

$$x_5 = \frac{a a_1 (b - b_1)}{a_1 b + a b_1}, \text{ similarly}$$

$$y_5 = \frac{b b_1 (a + a_1)}{a_1 b + a b_1}.$$

For the point P_4 the co-ordinates are

$$x_4 = 0, \qquad y_4 = b_1$$

Hence for P_2 we shall have

$$x_2 = n x_5 = \frac{n a a_1 (b - b_1)}{a_1 b + a b_1}$$

$$y_2 = b_1 + n(y_5 - b_1) = \frac{b_1(a_1 b + a b_1 - n a(b_1 - b))}{a_1 b + a b_1};$$

and for P_1, $x_1 = n a$, $y_1 = 0$.

Substituting these values of $x_1 y_1, x_2 y_2$ in the equation of a line through two points

$$(y - y_1)(x_1 - x_2) = (x - x_1)(y_1 - y_2)$$

we have after reduction,

(75) $$y = \frac{(n a - x)(a_1 b + a b_1 - n a(b_1 - b))}{n a (a + a_1)}$$

which is the required line.

Now in this equation we may give to b_1 any value we please, positive or negative; suppose it to change gradually in value from some positive quantity to some negative, the line G P_1 will change position accordingly, and at the instant in which b_1 passes through zero it will be tangent to the section through P_1; for the law of this curve of section is, that it cuts off an nth part of the portion of any radial line included between the two curves A V B and C V D; hence at the instant that $b_1 = 0$ the line G P_1 coincides with an element of the curve. In the figure G P_1 is this limiting case; *i. e.*, the tangent at P_1, and the line of equation (75) would cut the axis of y very slightly nearer to F, but the two lines would so nearly coincide for this position of $P_3 P_5$, that G P_1 is made to answer for both. Now in equation (75) make $b_1 = 0$ and we have the equation of the tang. to the curve of section.

(76) $$\therefore\ y = \frac{b(n a - x)(a_1 + n a)}{n a (a + a_1)}$$

For the intercept on Y let $x = 0$,

(77) $$\therefore\ y_0 = \frac{b(a_1 + n a)}{a + a_1}$$

or putting it into the form of a proportion,

(78) $a + a_1 : n a + a_1 :: b : y_0.$

Hence to draw a tangent at any point of a curve of section of a cow's horn surface by a plane parallel to the curve directrices, draw the vertical projection of the element through the point (V P supposed parallel to P F), and tangents to the curved directrices at their points of intersection with the element; lay off E H and P_1 I each equal to $P_3 O = a_1$; draw H F to the point of intersection of the tangents previously drawn, and I G parallel to H F; through G draw G P_1, then will G P_1 be the required tangent line; for

$$O H = O E + E H = a + a_1,$$

$$O I = O P_1 + P_1 I = n a + a_1,$$

and $O F = b$; $\therefore$ by (78) $O G = y_0$

We will now construct a hyperbolic paraboloid normal to the soffit, and intersecting it in the element R S. Since lines perpendicular to each other have their projections on a plane parallel to one of them perpendicular, the vertical projections of the normals can be drawn at once perpendicular to the tangents to the vertical projections of the curve directrices and the median section at the points R, U, and S. Their horizontal projections will be perpendicular to the horizontal traces of the tangent planes to the soffit at R, U, and S. These tangent planes will of course be the planes through the tangent lines to the soffit at R, U, and S, already drawn, and the element of the surface R S. Portions of their horizontal traces are $\alpha\beta$, $\gamma\delta$, and $\varepsilon\zeta$, to which the horizontal projections of the normals S a, U b, and R c are perpendicular. These three normals are the directrices of our c j s. To find an element of the 1st generation, pass a plane through one directrix and find the points where the other two pierce it; join these points by a right line; this line will be an element of the surface. Take, for convenience, the plane which projects a S on the vertical plane of projection, then b and c will be the points in which the other directrices pierce this plane; therefore a c is an element of the first generation. Any number of other elements may now be found by merely dividing up a c and S R, or a S and c R proportionally, as in Fig. 3. In the figure the horizontal projections of several elements of each generation are drawn, but the vertical projections of those of the first generation only.

Next the intersections of the c j s with the P F's and with the Ex s must be found. The vertical projection of the intersection of the c j s just constructed with the V P is the line η S^v, of which the portion drawn varies but little from a right line. There are a number of forms in which the Ex s may be cut. It may be a cylinder whose axis passes through O and is parallel to E H; or a co-axial cow's horn surface generated on the extradosal ellipses H I_1 G and E K_1 F; or the exterior surface of each course may be cut like the course M_1 Q_1 by one vertical plane through f and k, and one inclined through d, f_0 g and k; or each course may be cut in a series of steps, as in the course P N, by a number of horizontal and vertical planes. The last method would be preferable for the voussoirs at the ends of each course, however the others were cut.

Except in the case where the Ex s is cylindrical, no face of a voussoir can be cut by the aid of a templet. Cut first two plane faces on the stone precisely parallel for the ends of the voussoir. If the Ex s is to be cut in the manner of P N or P_1 N_1, it would be best to cut next the other plane faces of the voussoir of which patterns can be made from the drawings. Then apply the patterns of the heads and mark the lines on the stone, marking also the points where one or more elements of the ruled surfaces forming the soffit and c j s's pierce the plane of the head of the voussoir. The warped faces can then be cut by a straight edge. The soffit face should be cut first, and the elements forming the edges of the voussoir marked; then all the bounding lines of the coursing joint faces will be given on the stone, and draughts can be sunk by a straight-edge in a direction perpendicular to the soffit edges of the stone by which the c j s's may be cut.

The curves k^0 l m and n o p are the evolutes of the ellipses A K B and D I C, and are convenient in drawing the normals to these curves which are required.

The curved directrices of this arch we take elliptical so as to correspond with the curves cut from the soffit in the other methods by planes parallel to the P F.

In each of the drawings the direct span is 30 ft., the oblique 34.64 ft. α=60°, and the number of courses is 49.

It is evident from the drawing that if a perpendicular to the H P be erected at the point O, it will pierce the soffit in the line K I, which is parallel to the rectilinear directrix and lower than the highest points of the elliptical directrices, so that the crown of the arch curves downward toward the middle, from which peculiarity the surface derives its name, "cow's horn." Plainly, if this curvature were so great as to cause the median section of the soffit to be convex toward the springing plane at the crown, the arch would be unsafe; indeed, could not stand at all. We will investigate the conditions under which this will be the case, and to this end will obtain the equation of the surface. Let the line O X be the axis of X, O Z the axis of Z, and let the axis of Y be a vertical line through the origin O. The equations of the three directrices will then be

$$\left.\begin{array}{ll}(79) & \dfrac{(x+\varepsilon)^2}{a^2}+\dfrac{y^2}{b^2}=1 \\ (80) & z=-\delta\end{array}\right\} \text{Equations of D I C;}$$

$$\left.\begin{array}{ll}(81) & \dfrac{(x-\varepsilon)^2}{a^2}+\dfrac{y^2}{b^2}+1 \\ (82) & z=\delta\end{array}\right\} \text{Equations of A K B;}$$

(83) $x = 0, y = 0$, equation of OZ; in which $\varepsilon = 0°q = 0°r$, and $\delta = OK = OI = \frac{1}{2}$ distance between the faces of the arch.

The equation of a plane through the axis of z is

(84) $$y = m\,x$$

in which m = tangent of angle between plane and H P.

We will now find, by elimination, the co-ordinates of the points in which (79) and (81) pierce this plane, obtain the equations of the element through these points, and then eliminate the constant m. From (79) and (84) we obtain after reduction, and placing $a^2 m^2 + b^2 = k^2$,

$$x_1 = b\left[\frac{-b\,\varepsilon \pm a\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right].$$

Similarly from (81) and (84),

$$x_2 = b\left[\frac{+b\,\varepsilon \pm a\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right].$$

Also from (80) and (82) we have

$$z_1 = -\delta \text{ and } z_2 = +\delta.$$

Substituting these values of x_1, x_2, z_1, and z_2 in the equation $\frac{z - z_1}{x - x_1} = \frac{z_2 - z_1}{x_2 - x_1}$ of a line through two points in X Z, we have

$$(z+\delta)\frac{2b^2\varepsilon}{k^2} = 2\delta\left(x - \frac{-b^2\varepsilon \pm a\,b\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right)$$

and by reduction

(85) $$b^2\,\varepsilon\,z - a^2\,\delta\,m^2\,x - \delta\,b^2\,x = a\,b\,\delta\sqrt{a^2 m^2 + b^2 - \varepsilon^2 m^2}$$

which is one equation of the element through $(x_1\, z_1)$ and $(x_2\, z_2)$, equation (84) being another.

Squaring (85), introducing the value of m from (84), and reducing, we obtain

$$\delta^2\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right)^2 - \frac{2\,\delta\,\varepsilon\,x\,z}{a^2}\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right) -$$

$$\delta^2\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{x^2 z^2}{a^4}+\frac{\delta^2 y^2}{a^2 b^2}\right) = 0;$$

or factoring,

(86) $$\delta\left\{\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right)\delta - \frac{2\,\varepsilon\,x\,z}{a^2} - \delta\right\}\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{x^2 z^2}{a^4}+\frac{\delta^2 y^2}{a^2 b^2}\right) = 0$$

which is the equation of the cow's horn surface. If ε be taken negative, the obliquity of the arch will be in the opposite direction from that of Fig. 3.

Equation (86) contains only even powers of y, hence the surface is symmetrical with respect to the plane X Z.

If $z = \pm\,\delta$, it becomes

$$\frac{(x \mp \varepsilon)^2}{a^2} + \frac{y^2}{b^2} = 1,$$

the equations of the curved directrices.

If $x = 0$, we have $y = \pm\, b\sqrt{1 - \frac{\varepsilon^2}{a^2}}$, two right lines parallel to the rectilinear directrix.

If $y = 0$, then $z = \frac{\delta\,(x \mp a)}{\varepsilon}$.

If z = some constant $= n\,\delta$, we have the intersection by a plane parallel to the P F.

(87) $$\left\{\frac{x^2}{a^2}+\frac{y^2}{b^2} - \frac{2\,\varepsilon\,n\,x}{a^2} - 1\right\}\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{n^2 x^2}{a^4}+\frac{y^2}{a^2 b^2}\right) = 0;$$

and if $n = 0$, this becomes

(88) $$\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}\right)^2 - \frac{x^2}{a^2} - \left(1 - \frac{\varepsilon^2}{a^2}\right)\frac{y^2}{b^2} = 0;$$

the equation of the median section.

In (88) let $y = b\sqrt{1 - \frac{\varepsilon^2}{a^2}}$ = height above X Z of lowest point of crown of arch = ordinate of median section where $x = 0$.

$$\therefore \left(\frac{x^2}{a^2}+\left(1-\frac{\varepsilon^2}{a^2}\right)\right)^2 - \frac{x^2}{a^2} - \left(1-\frac{\varepsilon^2}{a^2}\right)^2 = 0;$$

whence by reduction

(89) $$x = \pm\sqrt{2\,\varepsilon^2 - a^2}.$$

This equation gives the x co-ordinates of the points in which a tangent to the median section at the extremity of its minor axis cuts the curve. In order that the arch may stand, these points must be imaginary.

In (89) when $\varepsilon > a\sqrt{\frac{1}{2}} > 0.7071\,a$, x is real;

" $\varepsilon = a\sqrt{\frac{1}{2}} = 0.7071\,a$, $x = 0$;

" $\varepsilon < a\sqrt{\frac{1}{2}} < 0.7071\,a$, x is imaginary.

The third of these cases is therefore the condition of stability.

The same result may be obtained by differentiating (88), placing $\frac{dy}{dx} = 0$, and making the condition that there shall be only one value of x for which y is a maximum.

In equation (86) if $\varepsilon = 0$, we have

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1,$$

a cylinder whose axis is O Z.

If $\varepsilon = a$, by transposing and extracting square root

$$\delta\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) - \frac{x\,z}{a} = \pm\,\frac{\delta\,x}{a},$$

the equation of two cones tangent to each other along the axis of z.

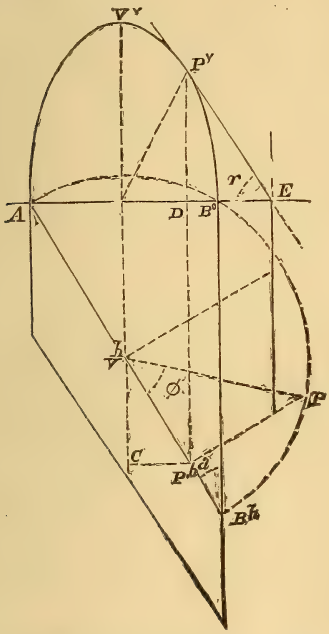
The equations of the c j s's can be found without difficulty, but they contain so many constants and are so complex as to be of no practical utility. The character of the arch as regards stability and tendency to sliding on the coursing joints, can be easily seen by examination of Fig. 3 and comparing it with Figs. 1 and 2. It will be noticed that the vertical projection of each element takes a direction between those of the normals to the elliptical directrices at the points where it cuts them; therefore at some point between these it must coincide with the vertical projection of the normal to the section at that point by the heading plane through it. It follows that at this point the element will be perpendicular to the direction which has been assumed to be that of the pressure, and from the manner of its construction the c j s will be also normal to this direction. At the crown this point is midway between the faces of the arch, and as we approach the springing plane it moves toward the points A and C. The curve λ U ϑ is cut from the c j s, R S $a\ c$ by a horizontal plane through the point U, and the portion of it from U toward ϑ which would lie upon the coursing joint would evidently be nearly perpendicular to the direction of pressure. The curve $\mu\ \nu\ \xi$ is cut from the coursing joint surface through the element M N, and the portion which is upon the voussoir is almost exactly perpendicular to the P F. $\mu_1\ \nu_1\ \xi_1$ is cut from the surface of the lower face of the same course M Q. $\pi\ \rho\ \varsigma$ is the curve cut from the c j s through the first c j c on that side by a vertical plane perpendicular to the P F through B. It varies but slightly in the distance $\pi\ \varsigma$ from a right line. $\pi_1\ \rho_1\varsigma_1$ is a similar curve cut by a plane through L. The first one or two c j s's from the springing plane vary so slightly from a plane in the portion included between the inner and outer surfaces of the arch that they might well enough be made *exactly* plane when the number of courses is large.

This method of constructing the arch gives results therefore, as regards tendency to sliding in the coursing joints, *intermediate* between those found in the two methods previously considered, but approaching far more nearly to those obtained in the logarithmic method; that is, the c j s's are nearly normal to the direction of pressure.

An arch may also be constructed with the cow's horn soffit and *plane* coursing joints as follows: On any element, as M N, take points midway between the heading planes, and at these points draw normals to the surface; through these normals and the element pass planes which will form the c j s's. The coursing joint will then be cut in a series of steps, and a portion of the voussoirs will have a triangular vertical face midway between the two ends. If the Ex s be also cut in steps, the voussoirs will have all their faces plane except the soffit, and all their edges straight lines except the intersections of the heading planes with the soffit. The construction of the drawings and cutting of the stones would thus be comparatively easy.

What was said in treating of the logarithmic method with regard to the limit of obliquity by reason of the edges of the voussoirs becoming too sharp where α is less than 60°, applies equally well to this method of construction. In this case, however, as in that, *segmental* arches can be built in which $\alpha < 60°$. Equation (51′) could be used to ascertain approximately the allowable span for a given radius and obliquity when the semi-axes of the elliptical directrices have the ratio to each other $\frac{b}{a} = \cos. \alpha$; that is, such that if the soffit were cylindrical, its right section would be a circle.

If the curved directrices are circles, we may obtain an approximate result as follows, by supposing the soffit to be cylindrical.



Let the angle $P_1V^hP^h = \Phi$,
" $P^vED = \gamma$,
" $AB^hB^\circ = \alpha$,
the distance $CP^h = x_1$,
" $DP^v = y_1$
and β = the angle between the P F and the tangent plane to the soffit (supposed cylindrical).

A V^v B° will then be a right section of the cylinder, and its equation will be, if $V^hP = r$,

$$\frac{x^2}{r^2 \sin^2 \alpha} + \frac{y^2}{r^2} = 1.$$

The equation of the tangent plane to the cylinder will then be

$$\frac{x\,x_1}{r^2 \sin^2 \alpha} + \frac{yy_1}{r^2} = 1$$

or

$$y = \frac{r^2}{y_1} - \frac{x_1}{y_1 \sin^2 \alpha} . x$$

$$\therefore \quad \tan \gamma = \frac{x_1}{y_1 \sin^2 \alpha}, \text{ and}$$

$$\sin \gamma = \frac{x_1}{\sqrt{x_1^2 + y_1^2 \sin^4 \alpha}}.$$

But by (51) $\sin \gamma = \frac{\cos \beta}{\cos \alpha} = \frac{1}{2 \cos \alpha}$ if we let $\beta = 60°$.

$$\therefore \quad \frac{x_1}{\sqrt{x_1^2 + y_1^2 \sin^4 \alpha}} = \frac{1}{2 \cos \alpha}$$

$$\therefore \quad 4\, x^2 \cos^2 \alpha = x_1^2 + y_1^2 \sin^4 \alpha.$$

Dividing by x_1^2,

$$4 \cos^2 \alpha = 1 + \frac{y_1^2}{x_1^2} \sin^4 \alpha.$$

We have $\tan. \Phi = \frac{y_1}{x_1 \operatorname{cosec} \alpha}$, whence $\frac{y_1^2}{x_1^2} = \tan^2 \Phi \operatorname{cosec}^2 \alpha$.

Substituting

$$4 \cos^2 \alpha - 1 = \tan^2 \Phi \sin^2 \alpha$$

$$\therefore \quad \tan \Phi = \frac{\sqrt{4 \cos^2 \alpha - 1}}{\sin \alpha} \text{ whence}$$

$$\cos \Phi = \frac{\tan \alpha}{\sqrt{3}}.$$

(90) Oblique span $= 2\, r \cos \Phi$

$$= \frac{2}{\sqrt{3}} r \tan \alpha = 2\, r . \frac{\tan \alpha}{\tan 60°}.$$

If α 30°, oblique span $= \frac{2}{3} r$.

If $\alpha = 45°$, oblique span $= \frac{2}{\sqrt{3}} r = 1.1547\, r$

In the cow's horn soffit this formula, as well as (51′), will make the diedral angles at the edges of the voussoirs in the first course slightly greater or less than 60°, according to their position in the course. The exact solution of the problem involves an equation of the 4th degree with four real roots.

COMPARISON OF THE THREE METHODS.

There is one advantage possessed by the helicoidal method over each of the others; viz., that it may be constructed of brick. This is owing to the fact that the successive c j c's are *parallel*, so that the voussoirs, except those at the ends of the courses, are all exactly alike, while in the other methods each stone is different from the next one, though the *two halves* of the arch on each side of the keystone are alike, so that any stone cut for one side will fit also in the corresponding place on the other side. The fact that the different voussoirs are alike in the helicoidal method, of course lessens the labor of preparing the drawings, and of making the necessary measurements. As regards the difficulty of *cutting* the stones, however, this method does not seem to have any serious advantage over the others even by the approximate method of cutting which has been mentioned, while if the coursing and heading joint faces were cut with exactness, as *helicoids*, the difficulty would be fully equal to if not greater than that by the other methods.

It may be considered an advantage as regards *appearance* that the quoin-stones should be all alike, or rather those faces of the quoin-stones which coincide with the faces of the arch. This, of course, is the case only with the helicoidal method. It appears to me, however, that the gradual decrease in the size of these faces from one side of the arch to the other would not be displeasing to the eye, when taken in connection with the direction of the c j c's which would make the *reason* for the decrease obvious. The real test, however, of the relative value of the different methods would appear to be that of *security*. When this test is applied, the logarithmic and cow's horn methods both excel by far the helicoidal. It has been shown that in the last mentioned, when semi-circular, there is *always* a tendency to sliding on the coursing joints, both above and below a certain point; that is, the assumed direction of pressure is nowhere normal to the coursing joints except at a certain height above the springing plane equal to r sin. 39° 32′ 23″, and that near the springing-plane this tendency to sliding increases rapidly with the obliquity up to $\alpha = 20°$ (about); while in the logarithmic method along each c j c this tendency is zero; that is, the assumed direction of pressure is normal to the c j s at any point of the c j c, and in the cow's horn the tendency is small as compared with the helicoidal.

The logarithmic method, therefore, seems to approximate to theoretical perfection as regards security, is followed closely by the cow's horn, and at a great distance by the helicoidal.

The cow's horn soffit admits of plane coursing-joints, as has been shown, which are not feasible in the others, and thus possesses an advantage over them, if such an approximate construction be desirable. If *cheapness* be an important item to be considered, the last-mentioned method would seem to present most advantages, as avoiding almost entirely the use of curved surfaces, and at the same time reducing the sliding tendency to a small amount.

If the main thing to be considered is *security*, the logarithmic method must stand first.

At Sea—very much.—Our contemporary *The Engineer*, in a leader in its last number on "The Bessemer Channel Steamer," announces that "it has been shown that the taffrail of an American liner often falls through a vertical space of 30 ft. in about one second when running in a heavy sea." If not asking too much of our contemporary, we should like to know how, when, and where this "has been shown." We ourselves never heard of the deck of a vessel falling so rapidly that the men standing on it were left behind; but, if our contemporary be correct, this must be a common although not ordinarily known occurrence. Ordinary individuals, as well as all inanimate bodies with which we are acquainted, only manage to get through a space of a fraction over 16 ft. during their first second when falling freely under the action of gravity, and if, therefore, an incautious sailor or passenger happened to be standing near the "taffrail of an American liner" when that vessel was about to perform the remarkable gymnastic feat which our contemporary records, he would at the end of a second find himself situated 14 ft. above the deck, surrounded by such loose articles as the deck near him might have carried before its descent! Our contemporary adds: "The effect of such a drop as this is beyond all question more severe than anything rolling produces." Quite right!—*Engineering.*

BRICK AND MARBLE IN THE MIDDLE AGES.

The work published a good while ago under the above title, containing Mr. Street's impressions and criticisms of architecture in the north of Italy, is now reissued in a second edition, forming a somewhat larger but still handy volume,* after undergoing considerable revision and additions at the hands of its author. Mr. Street has not, he tells us, found it necessary to alter his previous conclusions, so far as general principles are concerned, based on the study of Italian architecture; but in revising what he had previously written, he found himself obliged to make many alterations and additions, sometimes in relation to towns not visited on the first journey; sometimes in reference to buildings either not described or insufficiently described before. This has involved the rewriting of most of the book, though with the endeavor to interfere as little as possible with the general tone and character of its contents.

In its original form this work probably stimulated the interest, among English architects, in that combination of brick with marble in veneered or particolored designs which has so largely characterized the architecture of Mediæval Italy, and the avowed interest in which gave rise in great measure to the fancy for chequered and "stripy" brickwork in England, which critics have stigmatized by various contemptuous epithets. We cannot say that the influence of this form of Italian architecture on our own modern practice has been in the main for good. We have imitated mostly the less refined, certainly the less costly forms of it; we have got the brick *without* the marble, for the most part. That the process of marble veneer has not been employed here, at least not in that extensive and wholesale manner in which it is found in Italy, is a matter for congratulation; it is not in the highest sense an architectural form of treatment; it has more of the essence of cabinet work than architecture, and at best is only suited in expression to a climate of mild weather and bright suns. But the adoption of brick and marble in combination might have been very well used here and has been almost neglected, except in so far as the employment of marble shafts goes. We have instead of this, in our modern brick architecture, either very raw and crude combinations of strangely colored brick, or we have "stone dressings," in which a dead sandstone surface offers no contrast to the texture of the brick, but rather adds dulness to the whole. Part of the charm of brick and marble combinations consists in the contrast of texture—the smooth hard marble with the rough brick—and in the delicate tints obtainable from the marble. We have a good deal of the material within reach, but it has not been made the most of, even where expense was no obstacle to any wish or fancy of an architect. The Northern architect is like the refractory sons of the Bishop in Browning's poem; he refuses the marble, and will give us only stone. We have much need of more cheerful and less grim and dirt-holding materials in the architecture of our rainy and smoke-stained towns.

Independently of these more practical considerations, the interest of a comparative study of Italian, with Northern Mediæval architecture, is very great, even to those who feel less of positive interest in the style *per se*. The peculiar distinction between the condition under which the architect worked, and the results he produced, in the North and in the South, is very clearly brought out in the book before us. It points out how the Northern Mediæval architect developed his style away from the reach of the remains of Classic architecture, and with no precedents to divert his aim from the one style which he was engaged in almost unconsciously perfecting, without, practically, the knowledge of any other. The Italian was otherwise situated. He worked in a country with a great past, the architectural monuments of which were everywhere around him. And these architec-

* Brick and Marble in the Middle Ages: Notes of Towns in the North of Italy. By George Edmund Street, R.A. Second edition, with numerous illustrations. London: John Murray.

tural monuments belonged to a school of constructive design totally opposed to that which was dominant in Europe in the Middle Ages. They were the monuments and representatives of the great lintel system, which had died out with the decline and fall of the Roman Empire. The new structural form was that of the arch in its entirety, which had only been half accepted by the Roman, in a one-sided and architecturally apologetic manner, but was now to be carried to its utmost development by the Goth, whose influence was to become predominant throughout Europe. But in the midst of this permeation of the arcuated style, there lingered in Italy a constant tendency to a revival of, or return to, the antique forms, the remains of which were so plentiful, and the consequence was not only the existence here and there of groups of artists influenced by some one building of antiquity, which they admired, and were desirous of reproducing, in its best features, in their new work; but a general obstacle everywhere to the frank acceptance of the arcuated style as a system of balanced and buttressed construction. The old Classic principle of repose still asserted itself in the Mediæval art of Italy. The buttress was never made a feature in the design, except in the old Classic pilaster-like form; the arch was largely used, its pointed form was more or less adopted, though with hesitation, but its external constructive expression was shirked, and the obvious aim was to combine the Gothic arcuated construction with the Classic immobility of design and expression; or if this were not the conscious aim, it was the unconscious result of conflicting tastes and associations.

"They ignored as much as possible, the clear exhibition of the pointed arch, and even when they did use it, not unfrequently introduced it in such a way as to show their contempt for it as a feature of construction; employing it often only for ornament, and never hesitating to construct it in so faulty a manner, that it required to be held together with iron rods from the very first day of its erection. This fault they often found it absolutely necessary to commit, because they scarcely ever brought themselves to allow the use of the buttresses; and this reluctance was a remarkable proof of their Classic sympathies. . . . . . Italian architects, then, in never resorting to the buttresses, avowed their feeling that a state of perfect rest was the only allowable state for a perfect building, and they preferred almost always to use the arch for its beauty alone, and avowedly not for its constructional value."

From this use of the arch without the buttress grew, thinks Mr. Street, one beauty, the use of the frequent trefoiled arches so common in Italy, and which he regards as having their origin in an attempt to balance the arch by weighting it inward. As so much depended on these trefoiled arches, "no pains were spared in bringing their outline into the very purest form. To this we owe the absolute perfection which characterizes some of the trefoiled arches in early Italian work." Whether or no this may be attaching a little too much constructive importance to the trefoiled arch, there can be no doubt that to the half-hearted use of the arch referred to, as well as to the lingering of certain reminiscences of Classic art, is mainly due the want of unity of design and of entirely satisfactory character in the buildings of Mediæval Italy as compared with the best of Northern Gothic. "You may go to a great English cathedral and find that, from every point of view, inside and outside, every feature is well proportioned to its place, and beautiful in itself, while the *tout ensemble* is also perfect in proportion and mass. This can never be said of Italian work. It never produced anything perfect both in detail and in mass, and one always finds it necessary to make excuses for even the best works, such as one never finds necessary, or allows oneself to think of making, for English works. There is something really absurd in comparing even the best of the Italian churches with such cathedrals as those of Canterbury and Lincoln, so superior are the latter from almost every point of view."

We take the above extracts from the concluding chapter, in which the merits and defects of Italian Gothic buildings are summed up very comprehensively. Among other reminiscences of Classic design with which the Italian architect was haunted was the cornice, which was developed to an extent and with a richness never found in true Gothic work, and the heavy lines of which not only cap the walls horizontally, but are carried up gables and returned round buttresses. Many of these cornices (often brick) are very fine, and not without great effect architecturally; but it is obvious that they clash with the verticality of design which is predominant in true

Gothic. The mouldings of the Italian architect are what we should call poor and slight in effect, partly the result of a bright climate where deep cutting is not required to emphasize the shadows, and partly that frequent dealing with marble leads to a love for plain surfaces and sharp angles rather than for deep hollows and rounded angles. The traces of Classic influence on the plan, through the basilica form, are everywhere in Italian churches, which thus lack the multiplied outline and internal intricacy of the Northern cathedral; the latter quality being again interfered with by the wide spacing of the points of support by the Italian architect, who thus removed all appearance of mystery, and even destroyed completely the apparent scale of many of the largest structures in this manner. Among peculiarities due to Classic influence, our author points out with much commendation the constant use of the detached shaft, and especially its use in couples placed one behind another, so as to ensure lightness in the front view and yet give a full and varied perspective, with ample apparent strength. We quote the following very just remarks in regard to the respective merits of shafts and continuous mouldings:

"So long as the influence of Lombard and Romanesque art is visible in French, German, and English Gothic, so long the detached shaft was used, and just in proportion as in course of time that influence decreased, so did the frequency of its use decrease. Our fourteenth and fifteenth century buildings present nothing in its place but combinations of mouldings, in themselves very beautiful, but by no means so beautiful as to reconcile us to the loss of that which they so entirely supplemented. One consequence of their introduction, to the exclusion of the detached shaft, was, that the art of sculpture deteriorated just in proportion as the art of moulding was developed. There is no place in which architectural sculpture can be more fittingly displayed than in the capital of a column. It is the most convenient and at the same time the most conspicuous position for it. It is, too, the most important feature in every design in which the detached column is used. The gathering together of all the arch mouldings into one above the capital, in order that their forces may be collected before being transmitted to the ground, leads naturally to the laying of a special emphasis on this point above all others; and it is one of the strongest among the many reasons in favor of the earliest Gothic, and against the later varieties of the style, that in the former the use of the shafts involved the use of forcible and elaborately cut capitals, so that this point might be most distinctly marked, while in the latter, by the disuse of the shaft and the constant practice of carrying the mouldings of the arch down to the ground without any interruption, it was made as little of as possible."

The partiality of the Italian architects for detached shafts is further illustrated, we may observe, by the peculiar form of porch, consisting of a canopy supported by shafts generally resting on the backs of animals, which is found so frequently in Italian work. One of these, that of S. Maria Maggiore, Bergamo, forms the frontispiece to the present volume, and is a very good specimen of this elegant type of design, with which, however, great fault may doubtless be found if we take it from the standpoint of exact criticism. But there are many such features in architecture, which it would be ill-judged to imitate, yet which in their original form and locality are full of an interest partly artistic, partly archæological; we sketch them with a kindly feeling toward the workmen who invented such pretty fancies, and feel satisfied, on the whole, that there should be "incorrect" as well as "correct" architectural design in the world, and that artistic invention should never have moved for long in one fixed path, however satisfying it might be to the judgment. Among other uses of the shaft in Italy, Mr. Street alludes to the cloister of S. Gregorio, Venice, where the shafts support the woodwork in a very picturesque fashion without any arches; in fact, a reminiscence on a small scale of Classic construction, only that the lintel is wood instead of stone. There is among the drawings of French chateaux in the International Exhibition a similar construction, with admirable effect, in the formation of a recessed gallery under the eaves of the roof, which are carried by shafts in pairs at some distance from one another, supporting what we should now call a "trimmer" at the extremity of the rafters. Constructively, no doubt, wood upon stone shafts is not altogether workmanlike; and we may note this as another instance of that want of homogeneous character in construction and design from which arises much both of the interest and the defects of Mediæval Italian architecture.

IRON AND STEEL MAKING IN AMERICA REVIEWED BY AN ENGLISH IRONMASTER.

From the "London Mining Journal."

WHILE the ironmasters of Great Britain are awaiting a complete report from Mr. I. L. Bell of his visit to the iron and steel works of America, the views of a Staffordshire ironmaster upon what he saw during a tour of the iron and steel making localities of the United States have just been made known in a communication of much merit made to the South Staffordshire Mill and Forge Managers' Association, Wolverhampton. The author of the paper was Mr. W. Molineux, ironmaster, of Moxley, near Wolverhampton, who knew the United States iron trade as it existed a quarter of a century before. The progress that had been made in the interval, as well as in the using up as in the making of iron and steel, greatly astonished him; nor was he scarcely less surprised at the handy, compact, and generally efficient class of the machinery employed both in the iron mills and the steel shops. Much of this machinery the British iron and steel-master had not yet learnt to use in the way in which, with so much resulting economy, the Americans had learnt to use it. Nor had it yet been attempted by iron and steel makers in England to anything like the extent in which it was practised in America to make a profit upon the utilizing of the iron and steel which they produced. The excellent forge and mill arrangements, and the manner in which the iron and steel made was turned out completed goods at one establishment, he saw quickly upon landing, at the Passaic Rolling Mills of Cooks Brothers, at Patterson, New Jersey, only fifteen miles from New York. Here was in operation a three-high 16-in. forge train (of rolls), and a 16-in. universal mill at the end of the train. He did not know that in any forge-train in England the three-high system of rails was used, though three-high rolls were used—but not generally—in mills; and in only two or three instances was that which the Americans term the universal principle applied to rolls in this country. That principle obviated the use of grooved rolls in the rolling of bars, and saved the great delay and cost entailed by the frequent changing of rolls. The purpose was attained by the use of small vertical as well as the usual horizontal rolls. Thus by the shifting of the vertical rolls so as to bring them closer together, or remove them further apart, bars of any required width, up in this case to 16 in., might be rolled with the same horizontal rolls. There were steam-hammers in the same works, and slotting-machines, together with rivet-making and other similar machines for completing small work. The proprietors went in for as great a variety of products with as small but as complete a plant as possible. Nor did they neglect their operatives. By the use of water, which constantly trickled upon plates of iron suspended in front of the furnace doors, the inside of the works became cooler in hot weather than the outside. Further, by the use of what the Americans termed the "telegraph," the incandescent iron was conveyed from the furnaces to the hammers, and from the hammers to the rolls, suspended in the air, and there was little or no use, therefore, for that other source of heat in the works—floor-plates of iron. Close by Mr. Molineaux saw what in England was termed a drawing-out forge, where iron and steel of all kinds and sizes was being drawn out and turned, for cast-steel in pots was also made in the place, in eight furnaces, producing three heats per day. While he was in the forge a 10-ton crank was in the lathe, and a fine forging, exceedingly well finished it was. Connecting-rods, piston-rods, and so forth were also being thus produced. Likewise at Patterson he visited the three locomotive and engineering works, employing together 3,000 hands, making locomotives as good as any he had ever seen, and supplying the machinery required by twenty cotton and silk mills in the same town, as well as producing other first-class machinery.

At Albany there were two new blast-furnaces at work, producing 420 tons per week, and two more were being erected. Better furnaces he had not seen even in the North of England. Rolling mills and forges were also to be laid down by the proprietors of the furnaces, who had taken some fifteen or twenty acres of land for the purpose. The property was connected with the Hudson river and with the Erie Railway. A spacious three-storied building at Albany had been taken by a company for making agricultural machines.

Troy, with its Bessemer plant; Syracuse, with its works for making spring steel, and then Rochester, were passed in review; and it was pointed out at Ironton, ten miles from Niagara, two blast furnaces were in course of erection. The engine-house of these furnaces, which could not be matched for style and spaciousness in England, Mr. Molineaux described as having the appearance of a mansion fit for the abode of a man having an income of from £1,500 to £2,000 a year. Four furnaces were ultimately to be put up here, the proprietors having bought no less than 300 acres of land for the purpose of their works. The engine-house he had depicted was the home of two condensing engines, having 54-inch steam cylinders, 96-inch wind cylinders, and a 7-feet stroke. Twenty boilers, 55 feet long and 3 feet diameter, supplied the engines with steam; and there were eight or ten hot-air ovens to each furnace, so arranged that any one could at any time be cut off for repairs without interfering with the working of the furnaces. Lake Superior ore for these furnaces was being unloaded on the ground from vessels of 1,000 to 1,500 tons burden. It was being hoisted by hydraulic machinery to a platform 50 feet high, and thence dropped to the ground, apparently to accumulate mounds of it that high for use in the winter. Coal had, however, to be brought overland a distance of eighty miles, at a cost of $4 per ton. At Buffalo Mr. Molineaux went over Pratt & Co.'s ironworks, where there were two forges, twenty-three puddling-furnaces, two pairs of rotary squeezers and forge train, and a pair of universal rolls. Here, too, the firm were working up their own iron into numerous light articles, such as washers and nails of all kinds, including excellent horse nails, which the manager said they had been producing by machinery for eight or ten years, and he expressed surprise that England (according to the newspapers) had only just succeeded in adapting machinery to the making of horse nails. Nuts and burrs were being well got up at these works. They were pressed out in an exact square, and were otherwise completely and well executed. The firm expected a considerable addition to their business by reason of the International Bridge, which had been opened since Mr. Molineaux had returned home.

Two hundred miles further off he came to Newburg, near Cleveland, where there was an important Bessemer plant, having four blowers, and where they were removing the steam-hammers and putting down three-high blooming rolls instead. Here there were mills for rolling iron and steel rails, driven by an engine of 350-horse power. The manager (Mr. Howell) went out five years ago from Wolverhampton, where at Messrs. Sparrows' he worked as an assistant roll-turner. At these works there were also two 8-inch wire mills. The most recently erected of these had been fitted up at great expense, the chocks being made of Bessemer steel (plained to fit). Instead of liners for chocks, wedges were used, plained, fitted, and screwed-in in the nicest manner. Here, too, was a set of three-high 16-inch rolls for billeting down all their steel rail ends to a 2-inch by $\frac{5}{8}$-inch bar. In this shape the steel was charged into the mill furnace by a door at the back, and after being drawn out at the other side was rolled out into wire. Every pound of their Bessemer scrap they seemed to be using up in one way or another. The works had not been short of orders all the time Mr. Howell had been manager; and when, in the autumn of 1873, Mr. Molineaux was at the works, Mr. Howell said that they had orders on their books which would take them two years to execute.

At Chicago there were the North Branch Bessemer Works, having two blast-furnaces; two forges, with three high forge rolls; two rotary squeezers; two three-high rail mills—one for iron and one for steel; and everything as complete and efficient as possible, alike as to minimizing labor and permitting no waste.

At St. Louis there was an ironworks which had been laid down by an Englishman, which was as good nearly as it was twenty-five years ago, and this same

Englishman, who went out from Cleveland—and in doing so never, in Mr. Molineaux's opinion, made a greater mistake in his life—had designed no inconsiderable portion of the ironworks machinery of the States.

Upon calling at Ohio Falls ironworks, at New Albany, near Louisville, when his name was announced the manager, who was an Englishman, named Dangerfield, told him that he was at that moment reading an account in an American paper of a new furnace that he (Mr. Molineaux) had just put up at his works at Moxley. Now, that news from the date at which the fact was published in this country had travelled faster than he had himself, and he mentioned the fact to show how watchful an eye the American iron and steel masters were keeping upon what was being done in those industries in the old country.

Works at Cincinnati, at Youngstown, at Johnstown, and elsewhere, were described, and much significance attached to the Cambria works, at Johnstown, with its four blast furnaces, its forty-six double puddling furnaces, and its admirable and extensive steel-making and steel-working appliances. Space will not, however, allow us to do more now than to add that while Mr. Molineaux is profoundly impressed with the vast strides in iron and steel making and manipulating which the Americans have made in the past twenty-five years, still he does not despair of an excellent business being possible with them for a long time to come. They have, he says, much overdone the work of preparing to meet the American demand, and they have done this at a very heavy first cost. With moderate prices in England the British ironmaster, Mr. Molineaux believes, may safely calculate on keeping the United States as one of his customers. The two greatest difficulties with which the iron and steel producer of America has to contend are dear labor, and to some of the native markets, expensive land carriage. Illustrative of the cost of labor in the States, he pointed out that at the time the puddlers in this country were being paid the very high and unexampled figure of 12s. 6d. per ton, puddlers in America were paid nearly twice that sum; and he showed that a roller who had three hoop-mills in his care was from that source netting £1,000 a year, and was, moreover, the owner of a much-used livery stable. Relative to the expense of carriage to some of the American markets, Mr. Molineanx does not think that it costs much if any more to carry iron from some of the British ironworks across the Atlantic to New York than it does to take iron from Pittsburgh to that market.

A prohibitive tariff is what, in his opinion, English iron and steel masters have most to fear, but he does not believe in the probability of such a duty. He speaks most highly of the frankness with which American iron and steel makers everywhere, with one solitary exception, threw open to him the whole of their works. "We have," they said, "no secrets, and we will give you any explanation you need." The exception was that of some steel works which certain manufacturers from Sheffield had started near to Philadelphia. But even to those works he might, perhaps, have obtained admission if the proprietors had not been away. Specimens of the sheets, hoops, and horse-nails, and the like, which he picked up at random in passing through the works, Mr. Molineaux showed to the Association, and they were pronounced of much excellence. As he deserved to be, the author was very warmly thanked for his excellent paper, which bristled with facts from beginning to end, and was in no respect discursive.

An important project has been under consideration for some time by the Belgian authorities, for connecting the State railways and the centre of the town of Antwerp with the railways of the province of Waes by means of a tunnel under the Scheldt. The tunnel will descend at the rate of 0.002 per metre, from the left bank of the river, and have an ascent on the other side of not more than 0.015. The arrangements proposed are such that the passenger and goods services will be distinct from each other, a novelty deserving attentive consideration. The sections of line to be formed include no curves of less than 350 metres radius, and no inclines exceeding 17½ per 1,000.

ON THE EFFECT OF ACID ON THE INTERIOR OF IRON WIRE.

From "The Engineer."

It will be remembered that at a previous meeting of this society, Mr. Johnson exhibited some iron and steel wire in which he had observed some very singular effects produced by the action of sulphuric acid. In the first place the nature of the wire was changed in a marked manner, for although it was soft charcoal wire it had become short and brittle; the weight of the wire was increased; and what was the most remarkable effect of all was that when the wire was broken, and the face of the fracture wetted with the mouth, it frothed up as if the water acted as a powerful acid. These effects, however, all passed off if the wire were allowed to remain exposed to the air for some days, and if it were warmed before the fire, they passed off in a few hours.

By Mr. Johnson's permission, I took possession of one of these pieces of wire and subjected it to a further examination, and from the result of that examination I was led to what appears to me to be a complete explanation of the phenomena. I observed that when I broke a short piece from the end of the wire the two faces of the fracture behaved very differently—that on the long piece frothed when wetted and continued to do so for some seconds, while that on the short piece would hardly show any signs of froth at all. This seemed to imply that the gas which caused the froth came from a considerable depth below the surface of the wire, and was not generated on the freshly exposed face. This view was confirmed when on substituting oil for water I found the froth just the same. These observations led me to conclude that the effect was due to hydrogen, and not to acid, as Mr. Johnson appeared to think, having entered into combination with the iron during its immersion in the acid, which hydrogen gradually passed off when the iron was exposed. It was obvious, however, that this conclusion was capable of being further tested. It was clearly possible to ascertain whether or not the gas was hydrogen, and whether hydrogen penetrated iron when under the action of acid. With the view to do this I made the following experiments:

First, however, I would mention that after twenty-four hours I examined what remained of the wire, when I found that all appearance of frothing had vanished, and the wire had recovered its ductility, so much so that it would now bend backward and forward two or three times without breaking, whereas on the previous evening a single bend had sufficed to break it. I then obtained a piece of wrought iron gas-pipe, 6 in. long, $\frac{5}{8}$ in. external diameter, and rather more than $\frac{1}{16}$ in. thick; I had this cleaned in a lathe both inside and outside; over one end I soldered a piece of copper so as to stop it, and the other I connected with a piece of glass tube by means of india-rubber tubes. I then filled both the glass and iron tubes with olive oil and immersed the iron tube in diluted sulphuric acid which had been mixed for some time and was cold. Under this arrangement any hydrogen which came from the inside of the glass tube must have passed through the iron. After the iron had been in the acid about five minutes small bubbles began to pass up the glass tube. These were caught at the top and were subsequently burnt and proved to be hydrogen. At first, however, they came off but very slowly, and it was several hours before I had collected enough to burn. With a view to increase the speed I changed the acid several times without much effect until I happened to use some acid which had only just been diluted and was warm; then the gas came off twenty or thirty times as fast as it had previously done. I then put a lamp under the bath and measured the rate at which the gas came off, and I found that when the acid was on the point of boiling, as much hydrogen was given off in five seconds as had previously come off in ten minutes, and the rate was maintained in both cases for several hours. After having been in acid some time the tube was taken out, well washed with cold water and soap so as to remove all trace of the acid; it was then plunged into a bath of hot water, upon which gas came off so rapidly from both the outside and inside of the tube as to give the appearance of the action of strong acid. This action lasted for some time, but gradually diminished. It could be stopped at any time by the substitution of cold water in place of the hot, and it was renewed again after several hours by again putting the tube in hot water. The volume of hydrogen which was thus given off by the tube after it had been taken out of hot acid was about equal to the volume of the iron. At the time I made these experiments I was not aware that there had been any previous experiments on the subject; but I subsequently found, on referring to Watts's "Dictionary of Chemistry," that Cailletet had in 1868 discovered that hydrogen would pass into an iron vessel immersed in sulphuric acid. See *Comp. Rend.*, lxvi., 847. The facts thus established appear to afford a complete explanation of the effects observed by Mr. Johnson.

In the first place, with regard to the temporary character of the effect, it appears that hydrogen leaves the iron slowly even at ordinary temperatures—so much so that after two or three days' exposure I found no hydrogen given off when the tube was immersed in hot water. With regard to the effect of warming the wire—at the temperature of boiling the hydrogen passed of 120 times as fast as at the temperature of 60 degrees. Also when the saturated iron was plunged into warm water the gas passed off as if the iron had been plunged into strong acid; so that we can easily understand how the hydrogen would pass off from the wire quickly when warm, although it would take long to do so at the ordinary temperatures. With regard to the frothing of the wire when broken and wetted, this was not due, as at first sight it appeared to be, simply to the exposure of the interior of the wire, but was due to warmth caused in the wire by the act of breaking. This was proved by the fact that the froth appeared on the sides of the wire in the immediate neighborhood of the fracture, when these were wetted, as well as the end; and by simply bending the wire it could be made to froth at the point where it was bent. As to the effect on the nature and strength of the iron, I cannot add anything to what Mr. Johnson has already observed. The question, however, appears to be one of very considerable importance, both philosophically and in connection with the use of iron in the construction of ships and boilers. If, as is probable, the saturation of iron with hydrogen takes place whenever oxidation goes on in water, then the iron of boilers and ships may at times be changed in character and rendered brittle in the same manner as Mr. Johnson's wire, and this, whether it can be prevented or not, is at least an important point to know, and would repay a further investigation of the subject.

COMBINED ICE-BOAT AND FIRE ENGINE.—Messrs. Crighton, of Abo, Finland, have built and engined a remarkable little craft for the Russian Government. She is 82 feet long, 14 feet beam, and draws 6 feet. She is fitted with a pair of ordinary high pressure engines with 13-inch cylinders, and 18-inch stroke. To fit her for discharging the duties of a fire engine she is provided with two steam pumps, double-acting, with steam cylinders 8-inch stroke and 9-inch diameter, while the pumps are 4-inch diameter. The steam pressure is 60 pounds.

The vessel is specially intended to maintain communication between the island of Cronstadt and the main land. For a considerable portion of the winter the ice will carry any weight that can be put on it, but in the spring and autumn the ice, though too strong to prevent the use of ordinary boats, will not carry horses or sleighs. During the prevalence of westerly winds the ice, though broken up, becomes densely packed. The ice-boat is built of unusual strength, her skin being of $\frac{7}{16}$-in. and $\frac{1}{2}$-in. best boiler plates, double riveted throughout, her frames being of corresponding strength. In work she is driven straight at the ice, on which the bow runs until her weight breaks down a large mass, while at the same time fifty sailors roll her to keep her free from accumulations of ice on her sides, and this rolling is kept up all the time she is under weigh. She often sticks fast nevertheless, and has to back one hundred yards or so before she goes at the ice again with a rush. Some idea of the difficulties of this navigation in winter may be gathered by the fact that while in summer the passage is done by steamer in thirty minutes, the ice-boat is often seven hours in making it.—*Engineer.*

PATENT COTTON GUNPOWDER.

From "Iron."

The history of great inventions is full of the most curious anomalies and puzzling inconsistencies. Among the most remarkable of these we may count the fact that so little progress has been made in the manufacture of explosives since that almost pre-historic epoch when gunpowder was added to the list of destructive agencies at man's command. True it is that modern chemistry and modern enterprise have launched on the world, within the present century, various compounds possessing a destructive power far exceeding that of gunpowder; but the old-fashioned black powder still holds its own, with almost the identical form and composition which was devised by its first discoverer.

Like most other great discoveries (of pre-Yankee date), the secret of the direful properties of a properly proportioned mixture of sulphur, charcoal, and nitre, proceeded from the far East. There can be little doubt that the receipt had penetrated from China, or some other Asiatic country, into Europe before the eighth century, long prior to the time of Roger Bacon—first of English scientific worthies—or of the German Schwarz. Be this as it may, for considerably over a thousand years there has been little or no advance on the quaint injunction of Marcus Græcus, which might well be taken as a guide for the modern powder-maker—granting, of course, the improved mechanical appliances of these later times. How it was that a composition, closely approximating to that which an ultimate knowledge of chemical reactions and equivalents would have prescribed, should have been hit on, is a matter for curious speculation; unless, indeed, the secret was one of those dire gifts to mankind which escaped, alas! from Pandora's casket of evil.

Of late, however, as we have said, there have been strenuous efforts made to turn to profitable account other and more energetic explosives whose powers have been brought to light in the course of chemical research. Chief among these we may note gun-cotton, whose properties, and their applicability to military and technical purposes, have been studied with admirable perseverance by Continental *savants*, and subsequently in England by Professor Abel. After having fallen into disrepute, on account of the danger attending its manufacture and use, it received fresh importance from the improved process introduced by Lenk, which was adopted with the best results by Messrs. Prentice, at Stowmarket, till a disastrous explosion shook the confidence that had been established. Nitro-glycerine, first brought into prominence by Nobel, a Swedish engineer, seemed also to promise great results, till it was shown to be far less under control and more dangerous than even gun-cotton. In the diluted and safer form of dynamite, Messrs. Krebs of Cologne have been indefatigable in placing nitro-glycerine again before the public, and it may be held to be still on its trial. The dilution of an agent whose energy depends on its concentration is, however, an undesirable expedient, and, as in the somewhat analogous case of Gale's protective system of mixing gunpowder with powdered glass, is open to considerable objection. Lithofracteur, a modification of dynamite; dualin, an American explosive of great power, formed by adding nitroglycerine to saw-dust, and alleged to have fifteen times the power of gunpowder; with Horsley's, and other "white" powders, are all competitors for public favor as a substitute for gunpowder in ammunition, and for engineering purposes.

The most important undertaking in this direction at present existing in this country is, however, unquestionably that of the Cotton Gunpowder Company formed some time since to work what is known as Punshon's Patent. To their works at Oare, some four miles from Faversham, a goodly party of engineers, mining agents, and others, including several representatives of the army and navy, proceeded on Wednesday last to witness a series of experiments intended to illustrate the peculiar properties of the new powder. The company has secured about fifty acres of ground, swampily situated on the estuary of the Swale, a location which, for isolation, leaves little to be desired. The visitors being received at the gate by the courteous manager, Mr. S. J. Mackie, C. E., were first shown, as a preliminary to the trials, with the utmost frankness, the whole course of manufacture, which consists of the following processes. Ordinary raw cotton, after being roughly dressed, or "devilled," and cleaned, is soaked in a vat of strong mixed nitric and sulphuric acids. After a prolonged soaking of the cotton, the greater part of the sulphurous acid is squeezed out by an hydraulic press, the removal of the acid being carried a step further in a centrifugal machine, which reduces the weight by 50 per cent. After a long course of washing, to remove all traces of free acid, the cleansing being in the final tank assisted by the agitating effect of a current of air which passes through the water, the pulpy product is dried in a centrifugal revolving about 1,800 times in a minute. The dried gun-cotton is then weighed, and a definite proportion of an oxydizing agent is added. Though the nature of this substance was confided to us under reserve, it would possibly be considered a breach of confidence to publish it. The mixture is completed, and the mass thoroughly disintegrated into a fine powder under two copper edge runners in a pug-mill. The resulting powder having had the last particles of moisture removed under the influence of a stream of hot air passed through the perforated trays in which it is exposed, is now ready to be placed in cartridges.

There is a separate building devoted to the preparation of sporting powder. To produce this the ordinary powder has to be pressed into cakes and otherwise manipulated in a manner which has been productive of more than one explosion, and its manufacture has been for the present discontinued. That the fact of the attention of the staff being devoted to the production of blasting powder alone has been productive of the most satisfactory results, was demonstrated by the succeeding experiments. These were arranged to demonstrate alike the safety and power of the powder used, which was throughout that known as blasting powder No. 2 and No. 3. To illustrate the fact that the cartridges are harmless unless fired with a special detonator, various cartridges were burnt with impunity in the naked hand, while similar ones, fired by a detonator, produced explosions that induced the experimenters to keep at a respectful distance. Then followed an experiment which, though it resulted in an unexpected *contretemps*, was valuable as an indication of the perfect *bona fides* of the operators. Two cartridges having dynamite detonators attached, exploded in defiance of the programme, which insisted that they would *not* explode. It was explained, however, that these particular detonators were of extra quality, and that the occurrence was most unusual, while the probability of a lighted dynamite detonator being brought into proximity with the powder accidentally, is indefinitely small.

After two large barrels of the powder had been peacefully consumed on bonfires, affording nothing more alarming than a beautiful sheet of yellow flame—while the fall of half a ton of iron from a height of 15 feet failed to induce any action on the large bulk of powder on which it fell—it was pretty generally conceded, that so far as experiments can prove anything, they had demonstrated the possession by the patent powder of a singularly large measure of safety under ordinary and even extraordinary conditions. It seems at first sight so contrary to all that we should expect that a detonator should cause the violent explosion of a cartridge which no other treatment, whether by chemicals, by fire, or by impact, can prevail on to do more than harmlessly burn away, that it may be satisfactory to explain the probable *rationale* of the phenomenon. The miniature explosion of the detonator doubtless communicates simultaneously to each molecule of the powder vibrations of precisely the same periods—or length of swing—which the explosion of the powder itself would give rise to; thus by a species of inductive action does the trifling wave-motion of the detonator find its expansion and *denouement* in the extended but synchronous agitation of the exploded powder. This opinion is confirmed by the observation that while fulminating silver and iodide of nitrogen will not explode gun-cotton, the much milder detonation of fulminating mercury will do so instantaneously; this would of course follow on the hypothesis that the explosion of the latter substance propagates isoperiodic waves with that of gun-cotton, while the more violent explosives do not do so. Similarly may we account for the difficulty of preventing the concussion of an explosion of gunpowder from exploding adjacent magazines.

The destructive portion of the programme was not less decisive and conclusive in its teachings than the prior experiments. Among the more striking results attained was the rending into fragments (which were projected aloft in every direction) of four solid ingots of steel measuring 42 inches long by 11 inches square, and weighing 12 cwt. each, by a charge of 2½ lbs. of the blasting powder in cartridges simply fixed in between the ingots with clay. A similar group of smaller ingots, weighing 8 cwt. each, fared no better with a 2 lbs. charge. The huge fragments, rushing, hurtling through the air and ploughing rugged tracks over the fields, presented a most impressive spectacle, which was enjoyed by the visitors at a discreet distance, being, in fact, productive of an incipient stampede. A less imposing but practically valuable illustration was afforded by the splitting-up a large block of freestone by a 2-oz. cartridge placed in a shallow cavity. A heavy rail was also cut to pieces by an 8-oz charge simply laid on it without tamping, and a post 12 inches square was neatly snapped off by a cartridge (2 lbs.), hung loosely against it, being exploded.

As a variation, we were shown a 30-lb. charge, lightly covered with sods, instantaneously excavating a grave-like cavity over 20 feet long and 8 feet deep. Lest a suspicion should exist that interment, with its consequent damp, might prove fatal to its destructive power, it was demonstrated that powder, said to contain 20 per cent. of moisture, and to be incombustible by ordinary means, was by no means harmless.

An appropriate conclusion to a uniformly satisfactory series of demonstrations was found in the firing of a 50-lb. torpedo, sunk under 10 feet of water, which threw up a magnificent jet of water, some 200 feet high, with a force that would lead to the inference that the staunchest ironclad would prove an easy victim to such an infernal machine, were it once located under her hull.

At the lunch at which Major L'Amy (the chairman of the company) and the directors subsequently entertained their visitors, the customary complimentary toasts were received with unusual heartiness, there being a general feeling that great credit was due to all concerned for the admirable arrangements of the day.

Two additional points respecting the new powder, gathered from the day's investigations, are, that its state of minute division gives it a more certain and uniform composition with a smaller chance of any unduly acid portion escaping detection; the addition of an alkaline body also neutralizes any free acid and diminishes the chance of spontaneous combustion. Of its strength there can be no question, and the improbability of its exploding with any provocation short of the contiguous firing of a particular class —or classes—of detonators seems also tolerably evident. That so few precautions were taken on Wednesday, while the whole process was being peered into and explored by some score of inquisitive mortals in ordinary attire, appears to indicate that the company's officers share the opinion of Professor Attfield "that the patent cotton gunpowder is less dangerous to handle, transport, or store, than common gunpowder."

It is understood that the buildings and plant at present erected are able to produce about two tons of the powder a week, but provision has been made for their immediate extension so soon as the demand should justify the step. If actual experience in the ordinary routine of mining and military and engineering operations should confirm the expectations which experiments on a large scale reasonably hold out, it is probable that such a demand will speedily arise.

Railway communication in Russia is increasing rapidly. 12,000 miles are open to traffic in that country, while 3,000 more are in the course of construction. This is the more extraordinary, as Russia is not a country where railways are more required than common roads. As a necessary consequence of this increase of lines of railway, traffic is augmented rapidly, and the year 1873 shows an increase of 20½ per cent. for certain lines as compared with the previous years, while other lines show as much as 48 per cent.

LAST EXPERIMENTS ON SAFETY-VALVES.

From the "Nautical Magazine."

We are indebted to the Institution of Engineers and Shipbuilders of Scotland for a series of the most interesting and exhaustive experiments and reports on safety-valves ever yet undertaken or published; and the Council of the Institution have placed the engineering talent of the day under further obligation, inasmuch as they have published, in the form of a pamphlet, everything likely to be of value. The Committee of Council appointed to consider and report upon this all-important subject, were Messrs. Walter Brock (Peter Denny & Co.), James Brownlee, J. L. K. Jamieson (John Elder & Co.), Eben Kemp, H. R. Robson (Anchor Line), and David Rowan (David Rowan & Co.) These names are well known, and the conclusions in a report guaranteed by the whole of their signatures, may, we think, be taken as final, and as "absolutely without appeal."

To comprehend fully the value of this report, and its important bearing on the whole question, we must begin by enumerating a few points, viz.:

1. Until about fifteen years ago, it was not uncommon to find in marine boilers the proportion of area of safety-valves to fire-grate surface as one inch to the square foot.

2. About fifteen years ago, the Board of Trade sanctioned the use of a rule which then met with the requirements of the trade, whereby the proportion of area of safety-valves to heating surface was to be not less than half an inch to the square foot.

3. Pressures have been very much increased since then, and much abuse, but little argument, has been aimed at the Marine Department of the Board of Trade for not, from time to time, certifying as sufficient much smaller safety-valves.

4. The action of the Board of Trade proves that they have for some years known well enough, through the experience and reports of its practical officers, that even the old proportion of one inch area of valve to one foot of grate surface was not enough to relieve the boilers with their then low pressures, but also acted on the belief (see their circulars) that the present rule of half an inch to the foot did not require too large a safety-valve for modern high pressure boilers. The review of Mr. James Howden's paper, at page 941, *Nautical Magazine*, for 1872, is from the pen of a Board of Trade Surveyor, and indicates that that department have little to learn from even this valuable report.

5. Those interested in saving steam and fuel, argued that the old proportion of valve area to fire-grate was enough for the old low pressures, and that, therefore, that proportion ought no longer to be maintained for modern pressures.

6. The Board of Trade, it seems, have stood firm, and have taken no notice of the wholesale charges brought against them of "hampering trade," "interfering capriciously," "vexatiously interfering," and so forth, with machinery boilers and safety-valves, but have left the users of steam, and abusers of the Board, to prove their own case if they could.

7. The Institution of Engineers and Shipbuilders of Scotland, an impartial and scientific body, without views antagonistic to the Board of Trade, were moved by the spirit of truth to undertake the series of experiments the report on which they have now published.

We cannot, of course, reprint the whole of their valuable report, but we reproduce the following extracts, which practically contain the pith of it, so far as the outside world is concerned. The result of the whole investigation and experiments is, that the Board of Trade have been acting on proper advice in not reducing the areas of safety-valves, since at all pressures below seventy-two pounds the half-inch rule gives too small a valve. It is satisfactory, also, to see that the Committee report that in their scientific conclusions they have been, in *every instance*, anticipated by the Board of Trade staff. This corroboration is referred to in foot notes in the first part of the report, from which we have not quoted. The reaction formula adopted by the Committee was first published in this

Magazine as a diagram, in March, 1872, and in the same month was given in algebraic form in *Engineering* as a deduction by the Board of Trade staff, from fundamental principles and independent of experiments.

" RESULT OF A SERIES OF EXPERIMENTS,

made to ascertain the increase of pressure in a boiler when all the steam raised was allowed to pass away by the safety-valves unassisted. Two valves were used, the united area of which was half an inch per foot of grate surface. The boiler used was tubular, with two furnaces; the grate surface was 25 square feet; the heating surface, 746 square feet. The valves were each $2\frac{1}{8}$ inches diameter, the fuel used was ordinary good Glasgow dross, the firing good, and as nearly uniform during all the experiments as possible. The valves were loaded by direct weights. The following is table of results:

Load on Valve.	Pressure rose to.	Increase per Cent.	Lift of Valve.	W. Lbs.
5 lbs.	13 lbs.	160.	.325	3.39
10 "	19 "	90.	.255	3.223
15 "	25 "	66.	.18	2.68
20 "	30 "	50.	.16	2.676
25 "	36 "	44.	.1425	2.7
30 "	40 "	33.	.1262	2.58
35 "	44 "	25.7	.1125	2.466
40 "	$48\frac{1}{2}$ "	21.	.103	2.437
45 "	52 "	15.5	.097	2.41

" The valve seat being to an angle of 45 degrees,

$$W = \frac{3\ PL}{2.8D}$$

W = Weight of steam discharged per minute per square foot of fire grate.

P = Absolute pressure in lbs. per square inch.

D = Diameter of valve in inches.

L = Lift of valve in inches.

" Table showing the respective area of valve for the boiler in question, if made according to the Committee's recommendation, as compared with present practice in this country, and at the several undernoted absolute pressures:

Absolute Pressure of Steam.	Areas of Valve as Recommended by Committee.*	Areas of British Valves.
20 lbs.	45. square in.	12.5 square in.
25 "	36. "	12.5 "
30 "	30. "	12.5 "
35 "	25.7 "	12.5 "
40 "	22.5 "	12.5 "
45 "	20. "	12.5 "
50 "	18. "	12.5 "
55 "	16.36 "	12.5 "
60 "	15. "	12.5 "
65 "	13.84 "	12.5 "
70 "	13. "	12.5 "
75 "	12. "	12.5 "

" Safety-valves of ordinary construction, if loaded by direct weight, do not allow all the steam to escape which can be raised in the boiler, until the pressure has increased above that at which the valve opens, and an additional increase of pressure will take place when the valves are loaded by springs. That such has been the case in the past by dead-weight loading and imperfectly proportioned valves is fully illustrated by reference to the foregoing experiments.

" The object in appointing this Committee was to investigate the cause of this increase of pressure, especially with boilers proportioned in strength to work at low pressures, and it is hoped that the result of these investigations will clearly show that the great cause lay *in using valves of too small dimensions;* and that with valves proportioned as proposed, properly constructed and loaded by springs, anything approaching a dangerous increase of pressure is entirely avoided.

" ON LOADING SAFETY-VALVES BY DIRECT SPRINGS.

" It has been shown that valves having half an inch of area per square foot of grate surface require to lift

$$\frac{2 \times \text{diameter of valve}}{P}$$

in order perfectly to relieve the boiler; and if proportioned as is recommended in

* Our readers will be satisfied to find that up to 70 lbs. on the square inch, this Committee actually recommend *larger* valves than the Board of Trade ever required. This table would, therefore, hamper trade and increase the cost of navigation far beyond any legislative action taken in the matter.—ED.

this report, then the lift would be in all cases

$$\frac{\text{diameter of valve}}{36}$$

"Having determined the requisite lift, it remains to fix any reasonable or desired percentage of the load, which is not to be exceeded by the additional load due to the compression or extension of the spring caused by the lift of the valve. Let this, for example, be restricted to $2\frac{1}{2}$ per cent. of the original load.

"Then the spring loading the valve should be so proportioned that the compression or extension, to produce the initial load, shall be 40 times the lift of the valve.

"So that with valves having half an inch area per foot of grate surface, the initial compression or extension of spring would be $= \frac{80 \times \text{diameter of valve}}{P}$.

With valves as recommended, the initial compression or extension would be 1.11 $\times$ diameter of valve. The following formula refers to spiral springs, made of steel in the usual way:

E = Compression or extension of one coil in inches.

d = Diameter from centre to centre of steel composing spring in inches.

w = Weight applied in pounds.

D = Diameter or side of square of steel of which the spring is made in 16ths of an inch.

C = A constant which, from experiments made, may be taken as 22 for round steel and 30 for square steel.

$$E = \frac{d^3 \times w}{D^4 \times C}$$

The total compression or extension of such a spring is equal to that of one coil into the number of effective coils, which may be taken as two less than the apparent number, the end coils being usually flattened to serve as bases for the spring to rest upon.

"The relation between the safe load, size of steel, and the diameter of the coil has been deduced from the works of the late Professor Rankine, and may be taken for practical purposes as follows:

$$D = \sqrt[3]{\frac{w \times d}{3}} \text{ for round steel.}$$

$$D = \sqrt[3]{\frac{w \times d}{4.29}} \text{ for square steel.}$$

"The application of the above formulæ may be illustrated by the following calculations of three different proportions of springs, all designed to give the same result. Diameter of valve, 4″ = 12.5 area in square inches. Boiler pressure 60 lbs. per square inch. Omitting weight of valve, spindle and spring; load required = 12.5 $\times$ 60 = 750 lbs. Then, assuming that this valve is in the proportion of half a square inch area per foot of grate surface, the lift of valve would be $= \frac{2 \times 4}{75} = .106$, say .1″.

Initial compression of spring, $\frac{80 \times 4}{75} = 4.26''$, say 4 inches.

"1st. Supposed diameter of spring, or *d*, equal 4 inches $D = \sqrt[3]{\frac{750 \times 4}{3}} = 10$, diameter of spring steel $= \frac{10}{16}$. $E = \frac{64 \times 750}{10{,}000 \times 22} = .218''$. Effective number of coils $\frac{4}{.218} = 18.3$, say 18. Pitch of spiral, allowing between each coil a distance equal to twice the intended compression = 1.061″, say 1 inch; effective length of spring = 18 $\times$ 1 = 18″, and allowing for two end coils as bases, say $19\frac{1}{2}''$, = the length of spring before compression.

"2d. Supposed diameter of spring, 6 inches $D = \sqrt[3]{\frac{750 \times 6}{3}} = 11.447$, say $\frac{12}{16}$. $E = \frac{216 \times 750}{20{,}736 \times 22} = .355''$. Effective number of coils required, $\frac{4}{.355} = 11.2$, say 11. Pitch of spiral 1.46″; effective length of spring 1.46 $\times$ 11 = 16.06″, and allowing for two end abutment coils, say $17\frac{1}{2}''$ = the length of spring before compression.

"3d. Supposed diameter of spring 12 in.

$$D = \sqrt[3]{\frac{750 \times 12}{3}} = 14.42, \text{ say } \tfrac{14}{16}.$$

$$E = \frac{1,728 \times 750}{38,416 \times 22} = 1.533''.$$ Effective number of coils required, $\frac{4}{1.53} = 2.61$.

Pitch of spiral, 3.9″; effective length of spring, $3.9 \times 2.61 = 10.17''$, say 10″, and allowing for two end abutment coils, say $11\frac{3}{4}''$ = the length of spring before compression.

"In cases where it is desirable or perhaps necessary to employ springs acting at the ends of levers, the same formulæ can be employed for determining the proportion of springs, bearing in mind that the lift of the end of the lever where the spring is attached, is to be taken instead of the simple lift of valve.

"The above illustrative calculations have all reference to springs made of round steel, and used in compression. In many cases two or more springs, one within the other, may be used with advantage."

After consideration of the whole of the experimental information obtained, and the necessities required in practice, the Committee have come to the following conclusions:

"1st. The present practice in this country of constructing safety-valves of uniform size for all pressures is incorrect.*

"2d. The valves should be flat-faced, and the breadth of face need not exceed one-twelfth of an inch.†

"3d. The present system of loading valves on marine boilers by direct weight is faulty, and ill-adapted for sea-going vessels, a considerable quantity of steam being lost during heavy weather, in consequence of the reduced effect of direct load—the result of the angle or list of the vessel, and also of the inertia of the weight itself, the latter not being self-accommodating at once to the downward movements of the vessel, and, moreover, the impossibility of keeping the valves when so loaded in good working order.*

"4th. That two safety-valves be fitted to each marine boiler, one of which should be an easing valve.

"5th. The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:

$$A = \frac{18 \times G}{P} \text{ or } A = \frac{0.6 \times HS}{P}$$

A = Area of valve in square inches.

G = Grate surface in square feet.

H S = Heating surface in square feet.

P = Absolute pressure in pounds per square inch.

"6th. The Committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing-valve. The other may be so constructed as to lift one-quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers:

$$A = \frac{4 \times G}{P} + \text{area of guides of valve.}$$

$$\text{Or } A = \frac{.133 \times HS}{P} + \text{area of guides of valve.}$$

"This valve should be loaded, say 1 lb. per square inch less than the easing-valve.

"7th. As experience in the use of valves of this description is acquired, both may be of this kind, and one of them made to blow into the sea without any increase of pressure (as is illustrated by a diagram), from actual practice; the other to be the easing-valve, and loaded 1 lb. per square inch in excess of the working valve.

* Good. But as the Board of Trade rule is proved to be quite right for pressures between 70lbs. and 75lbs., and in favor of the steam user at lower pressures, is it worth while to alter it? If so, it must be on the ground that it should be altered for pressures above 75 lbs.; but the Committee have not shown in their table what the sizes for those pressures should be. Surely, 75 lbs. is a high enough pressure for any steamer to carry when lying at a quay. Whatever be the working pressure originally allowed on the boiler, the valves ought to be large enough to be safe when that pressure has been reduced to 75 lbs.—Ed.

† This recommendation is a wise one; and we already made it; and as there is not, and never has been any rule against it, it will probably be adopted.—Ed.

* We are glad to read this paragraph. The *Nautical* has always been in favor of trying spring-valves, and was the first to take up this subject in earnest. We offered a prize for the best spring safety-valve, and awarded it to one with a direct spring.—Ed.

"8th. If the heating surface exceeds 30 feet per foot of grate surface, the size of safety-valve is to be determined by the heating surface.

"9th. As boilers decay from age it is necessary gradually to reduce the pressure of steam, and the Committee recommend that valves should be made of a size to suit the pressure to which the boiler may ultimately be worked when it becomes old.

"10th. Springs should be adopted for loading safety-valves, and they should be direct acting where practicable.

"When levers are used, the friction of the joints will cause an extra resistance, and consequent increase of pressure, when the valve is rising, and a loss of steam through diminution of pressure before it will close.

"(Signed) WALTER BROCK,
JAMES BROWNLEE,
J. L. K. JAMIESON,
EBEN KEMP,
H. R. ROBSON,
DAVID ROWAN,
Committee."

We have given these extracts in connection with our point No. 7. We will now conclude by stating one point more.

8. A paper by Mr. James Howden, entitled "The Board of Trade Rule on safety-Valves," read before the Institution of Engineers and Shipbuilders in Scotland in 1872, and circulated extensively in pamphlet form under the auspices of the Institution, asserted that the Board of Trade required far too large safety-valves for the high pressures now generally carried in steamers. A review by a Board of Trade surveyor in the *Nautical Magazine* for November, 1872, utterly demolished every assertion made in Mr. Howden's paper. Our reviewer regarded it as a paper produced by one having no knowledge of the dynamic principles of elastic fluids. Our reviewer reconstructed, according to the views held by the Board of Trade staff, the tables given erroneously by Mr. Howden. It is to settle these points that the Institution undertook and completed these experiments.

Mr. Howden had asserted that for all pressures given in his tables the Board of Trade rule required too large a valve, and he further said that at 65 pounds pressure, gross, the Board of Trade required 80 per cent. too much area. The members of the Institution, without a single dissentient, accepted Mr. Howden's paper as correct, and pledged themselves to agitate for a reduction in this (then said to be absurd) requirement of the Board of Trade. They said the Board ignored the true principle that regulated the escape of steam. The Board of Trade staff said, on the contrary, that they were right, and that the paper circulated by the Scotch institution was totally wrong. The Board of Trade staff then said that at the above pressure, 65 pounds, and under the conditions laid down by Mr. Howden, the Board of Trade rule was exactly correct, and for all lower pressures it required too *small* a valve, and for all higher pressures it was a little in excess. The Scotch report now published is identically corroborative of the Board of Trade statement; but, having adopted slightly different conditions, it gives 72 instead of 65 as the gross pressure up to which the Board of Trade rule gives too *small* a valve.

The report is altogether ungenerously silent about Mr. Howden's very loud paper; but twice, in special foot-notes, records corroborations of the formulæ that had been given by the Board's officer; and, finally, the report makes a recommendation which is the adoption of a formula constructed by Board of Trade surveyors to represent the tabulated Prussian law when this matter was before considered by the Board. The paragraph in *Engineering*, from which that formula is said to be taken, happens to be, with the table following it, a verbatim copy of a Board of Trade *official* document, obtained by *Engineering* from the Marine Department on applying for information about safety-valve practice. Further, there is not established in the whole report a single fact either by investigation or by experiment that was not actually in the possession of the Marine Department of the Board of Trade (long before these experiments were even thought of), being the deductions from original investigations, or the result of new experiments by their own officers. We think it would only have been graceful and manly had the Institution of Engineers and Shipbuilders recognized specifically in their report, that not only had the experiments shown them that larger safety-valves are required than they had formerly contended, but that they had also now at last learnt that the Board of Trade had been right in their practice, and had all along known more about the true principles of the action of safety-valves than the reporters had given them credit for. In fact they might, had they been so disposed, have said with complete truth that, however deep the Committee had been able to go into the subject, they found at every point that the Board of Trade staff had been there before them.

ON RECENT DISCOVERIES IN MECHANICAL CONVERSION OF MOTION.

BY J. J. SYLVESTER, LL.D., F.R.S.

From the "Proceedings of the Royal Institution."

THE speaker stated that the subject he proposed to bring under the notice of the meeting related mainly to the discovery of a perfect parallel motion—that is to say, of a mode of producing motion in a straight line by a system of pure link-work without the aid of grooves or wheel-work, or any other means of constraint than that due to fixed centres, and joints for attaching or connecting rigid bars. This important discovery was made by M. Peaucellier, an officer of engineers in the French army, and first published by him, in the form of a question, in the *Annales de Mathematique*, in the year 1864, and subsequently formed the subject of two communications to the "Societe Philomathique" of Paris by Captain Manheim, but seems not to have received the attention it deserved from that learned body, and may be said to have passed into oblivion; so much so that when rediscovered by a young student of the University of St. Petersburgh, of the name of Lipkin, several years subsequently, the discovery was attributed to Lipkin instead of to Peaucellier, even in works published in the French language, and so recently as 1873 by M. Colignan, in his "Traite de Cinematique." The eminent Professor Tchebicheff had long occupied himself with the question, but with less than his usual success in overcoming difficulties insuperable to the rest of the world. Lipkin was a student in his class, and may thus have had his attention turned to the question; at all events, Professor Tchebicheff's warm interest in the subject was displayed by his bringing Lipkin's name before the Russian government, and securing for him a substantial reward for his supposed original discovery. Before Peaucellier's time all so-called parallel motions were imperfect, and gave merely approximate rectilinear motion; in substance, they will be, without exception, found to be merely modifications of Watt's original construction, and to depend on the motion of a point in, or rigidly connected with, a bar joining the extremities of two other bars rotating round fixed centres, which may be described briefly as three-bar motion. Peaucellier's exact parallel motion depends on a link-work of seven bars moving like Watt's, and the other imperfect parallel motions of the same class, round two fixed centres.

To understand the principle of Peaucellier's link-work, it is convenient to consider previously certain properties of a linkage (to coin a new and useful word of general application), consisting of an arrangement of six links, obtained in the following manner: First, conceive a rhomb or diamond formed by four equal links joined to one another; and now suppose a pair of equal links to be joined on to two opposite angles of such figure and to each other. All six links are supposed to lie (and to be constrained by the nature of their attachments to remain) in the same plane. The point of junction of the last-named pair of links (which it will be found convenient to call the fulcrum), according as they are greater or smaller than the sides of the diamond, will lie outside or inside the diamond.

The linkage consisting of the six links may be termed a positive *cell* in the one case and a negative *cell* in the other. It is easily seen, as a geometrical necessity, that the fulcrum, in whatever way the linkage is moved about, will always lie in a straight line with the two free angles of the diamond, which may be called its poles, and the distances of these poles from the fulcrum, or the ideal lines which represent those distances, may be called the arms of the cell. It is upon the geometrical relation between these arms that the remarkable mechanical properties of Peaucellier's cell depend. The cell may be made to change its form like a set of lazy-tongs or any other kind of linkage, by closing or opening the diamond; as this is done, evidently the lengths of the arms alter; but it will be found, and is capable of easy geometrical proof, that they remain subject to a very simple condition; viz., one increases just as much as the other decreases, so that their product remains invariable; this product is equal to the difference between the square of either of the links (called the connectors) proceeding to the fulcrum and the square of any side of the diamond, to which we may give the name of the modulus of the cell. The speaker illustrated this property experimentally, using a negative cell for the purpose. When the fulcrum was midway between the two poles, each arm was 12 inches in length. When one arm was made 18 inches the other was found to be 8; when again it was stretched to the length of 24 inches the other was 6, and so on, the product of the two remaining always 144; or, reckoning in feet, to the lengths 1, $1\frac{1}{2}$, 2, 3 of one arm corresponded the lengths 1, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ of the other, showing that the length of one arm was so governed by the length of the other as that the numbers denoting the two were always inverse or reciprocal to each other when the modulus is taken as unity. Hence a Peaucellier's cell may be conveniently termed a reciprocator or invertor. If we were to suppose the connectors at their free ends, instead of being attached to the side angles of the diamond, to be joined on to two adjoining sides in such a manner as to become parallel to the other pair of sides, this parallelism would continue to subsist for all positions of the linkage, and the arms or distances of the fulcrum from the opposite angles or poles of the diamond would still remain in the same right line; but the relation between them would now be one of direct instead of inverse proportion. Conceive the fulcrum in such an arrangement to become fixed. Since we cannot only alter the angles of the diamond, but make the whole arrangement turn round the fixed point, we can make either pole describe any plane curve whatever; the other pole will then describe a curve precisely similar in shape, but drawn on a different scale, as in any ordinary pantigraph.

But if we revert to the Peaucellier cell or reciprocator, whether of the positive or negative form, and treat it in the same manner as the supposed pantigraphic arrangement, fixing the fulcrum, and making one of the poles—*i. e.*, an extremity of one of the arms—describe any plane curve, the other pole would no longer describe a similar curve, but what in the language of geometry is termed an inverse of the curve in question, the fulcrum being the origin of the inversion.

Suppose now one of the poles is made to describe a circle, the other will describe the inverse of a circle, which geometricians are well aware will in general be another circle, subject to the exception, that if the arc described by one pole is part of a circle passing through the fulcrum, which is here the origin of the inversion, the path of the second pole will be no longer a circle, but a perfect straight line, which, under a mathematical point of view, may be regarded as a circle with an infinite radius. If then, in addition to fixing the fulcrum, we still further constrain the motion of the Peaucellier cell by attaching one of the poles to a centre (which, for the sake of distinction from the other fixed point above defined, we may term the *pivot*), round which it can revolve, situated at an equal distance from that pole and the fulcrum, the other pole will describe a perfect straight line perpendicular to the line joining the fulcrum and the pivot. We have thus a combination of seven radiating bars attached to two fixed centres, one point of which describes a true rectilinear path, and thus the long-sought-for problem of a perfect parallel motion meets for the first time its complete solution.*

The speaker illustrated these results by various models constructed in wood. By changing the length of the radial bar connecting one pole of the cell with a fixed point, the free pole was shown to describe arcs of circles convex or concave to the fulcrum, according as the ideal circle, in an arc of which the first-named pole moved, fell short of the fulcrum or contained that point within it; in the limiting case, when it passed through the fulcrum, the path was shown to be neither convex nor concave, but a straight line free from all curvature in either direction. This was further verified mechanically by connecting together at their free poles two perfectly equal and similar mounted cells. If the tendency of either of these was to deviate from the straight path, the tendency of the other would be to deviate in the contrary direction; so that either the pair of mounted cells would become an absolute fixture, or the two would crush or tear each other to pieces; but in the experiment exhibited the pair of mounted cells were seen to move together (as if in happy wedlock), without let or hindrance to each other's motion. The circular motion of the free pole of a single mounted cell in the general case was also verified experimentally, and even more simply than in the rectilinear case, by the addition of a second radial bar, taken of a suitable length, determined by previous mathematical calculation. As a general rule, the total number of bars in a link-work machine must be odd; but here there were eight bars, and yet the combination admitted of being set in free motion—any one of the eight being, in fact, what may be termed a lazy-bar, and capable of being removed without disturbing the motion, very much in the same way as any one of the four legs of a table may be removed without disturbing the equilibrium.

The speaker pointed out the important applications of the two kinds of motion above referred to (which he proposed to call the circulo-linear and the circulo-circular respectively) to various constructions in machinery, such as the steam-engine, planing and grinding machines, the construction of maps on the stereographic projection, millwrights' work, laying out of railway curves, dioptric apparatus for light-houses, ornamental tracery, pendulum suspension to effect motion in a practically exact cycloidal arc, etc., etc., and referred to the use which, as he was informed by the authorities at Woolwich, might have been made of the circulo-circular adjustment in saving several weeks' work, inconvenience, and expense in cutting out the fish-bellied torpedo casings recently constructed in the laboratory department of the Royal Arsenal there, and the use contemplated to be made of the circulo-linear or perfect parallel motion for guiding a piston-rod in certain machinery connected with some new apparatus for the ventilation and filtration of the air of the Houses of Parliament, now under course of construction.

He next referred to the unlimited command over the motion of a point furnished by a combination of cells. Returning to the simple Peaucellier cell, its use may be modified in a very remarkable manner by setting free the point of junction of the two connectors (termed in what precedes the fulcrum), and fixing one of the poles as a centre of rotation in its place. If now the liberated fulcrum be made to describe any curve, the free pole will describe a curve corresponding to it, according to a certain easily-stateable mathematical law. Imagine the first-named curve to be part of a circle passing through the fixed point; it may be shown that in that case the free pole will describe the inverse of a conic section in respect to a vertex of the conic as the origin of the inversion; consequently, by

* The centre above spoken of may be taken in the line itself, which joins the poles and the fulcrum. If it be taken not too far out of this position of symmetry it will in the course of the motion be brought into such position; but if it be taken at starting (as it may be), at a sufficiently great distance from the cell, the position of symmetry may never be attained throughout the whole possible course of the motion. This circumstance has been generally overlooked, and accordingly too narrow a rule has been given for the construction of a Peaucellier parallel motion, viz.: it is laid down that the pivot is to be taken midway between the fulcrum and one of the poles for some certain position of the instrument. The position of the fulcrum relative to the two poles gives rise to the distinction between a negative and positive cell; but the preceding remark shows that there is a further subdivision of Peaucellier parallel motions depending on the length of the mounting radius, and that positive and negative mounted cells each of them embrace two radically different forms or genera, which may be distinguished as the symmetrical and non-symmetrical respectively; in the one form there exists a position where the *first* lies in the line containing the *fulcrum* and the two poles, in the other, no such position can be found. In the ordinary rule given for the construction of a P. P. M. only the former of these two genera is included which, as machines, differ between themselves as much as do the ellipse and hyperbola as curves.

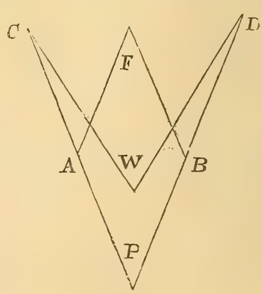
combining with this cell a second, used as a reciprocator, we may, mounting with a suitable radius a pair of Peaucellier cells duly adjusted, cause a point to move in a parabola, ellipse, or hyperbola.

The speaker exhibited a combination of this kind, and caused a point to describe portions of an ellipse, a parabola, and of the two branches of a hyperbola in succession; the traversing pole of the first cell, which might be termed the first follower, being seen to describe beautiful nodal cubics (or the inverses of the conics), while the free pole of the second cell or second follower described the conics themselves.

He next went on to state that by a combination of cells properly proportioned and suitably attached to each other in succession in a manner similar or analogous to that in which simple machines, as, for example, a number of levers, may be combined to produce a complex one, we are able to bring about any mathematical relation that may be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine. He exhibited and worked a cube-root extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients of the duplication or multiplication of the cube. This machine consisted of a combination of three cells; by changing the modulus of one of the three, he explained that it was also quite easy to solve the cubic equation involved in the analytical solution of the problem of the trisection of the angle; and a working model of an instrument of this kind executed in zinc was exhibited by Professor Henrici after the lecture. He concluded by expressing his great obligations to this gentleman, without whose aid he would have been able to do little more than adumbrate in general terms, the results which, thanks to his friend's practical knowledge and skill, he had had the pleasure of exhibiting in a tangible form, and submitting before his audience to the test of actual experiment; and expressed his conviction that Peaucellier's unhoped-for discovery (even if viewed merely on its practical side as a new vital element of mechanism) was destined to produce lasting and important results through innumerable applications to the useful and ornamental arts, and would hand down the name of its inventor to posterity as one of the benefactors of mankind.

In some possibly forthcoming number of "Nature" a detailed account, which was expected to appear two months ago, will be given, illustrated with the necessary diagrams, of the cube-root extractor and angle-trisector; the materials for this purpose are in the hands of the editor of that journal, and have been entrusted by him to the most competent person to draw them out into form—the writer not feeling within himself the necessary energy for accomplishing this task. He thinks it, however desirable (indeed almost a moral duty on his part) to supplement those materials by the desultory remarks which follow, in order that some results, which he believes to be important to the progress of mechanical and algebraical science, may be rescued from the chances of total oblivion and virtual annihilation.

The first question which presents itself relates to the square-root extractor. It is a remarkable fact that a cellular system for extracting square roots is much more complicated than what is required for the cube root; and so in general all even-degreed extractors require a more extensive apparatus of link-work than is required for the odd degrees. Such extractions may be performed in all cases by a system consisting of Peaucellier cells exclusively; but the process may be abridged in the case of even degrees by the interpolation of another form of cell, alluded to in a previous foot-note under the name of the quadratic-binomial extractor, which deserves a somewhat more detailed description. It is figured in the diagram below. F A P B is a jointed rhomb



or diamond; P C and P D are each doubles of the sides of the rhomb, and C W, D W are two equal links. The difference between the squares of C P and C W is the modulus. F P, F W are the arms, and the difference between their squares is equal to the modulus. This is the instrument which, when F is fixed and P moves in a circle passing through W, describes a curve which may be called the Lemniscatoid, having the same general kind of relation to the Lemniscate that the Hypercissoid and Hypocissoid bear to the Cissoid proper. The Lemniscatoid becomes the Lemniscate when a certain simple arithmetical relation subsists between the modulus and diameter of the circle described by P. If A as well as F be fixed, P will move in a circle passing through F, of which C P will be the radius, and consequently the five-bar linkwork, consisting of the links C W, C P, D W, D P, F B (centred at F and A), will serve to describe the Lemniscate when the arithmetical relation above referred to subsists between C P and the modulus; *i. e.*, between C P and the difference of the squares of C P and C W; consequently when the lengths C P, C W have a certain simple arithmetical proportion to each other, W will describe the Lemniscate; this proportion, it will be found, is such that when W comes to F the angle at P is a right angle. So much for the binomial root extractor; obviously by aid of this kind of linkage when one arm is the tangent of any angle, the other arm may be made equal to the secant, and *vice versa*. Again, it should be observed that, as in the Peaucellier cell (used as a reciprocator), the arms may be taken as x and $\frac{1}{x}$ by interchanging the fulcrum with one of the poles—*i. e.*, reckoning the two arms as the distance between the fulcrum and one pole from the other pole to the arm x—the new arm may be made to become $\frac{1}{x} - x$, which may be reciprocated into $\frac{2x}{1 - x^2}$ by the use of a second Peaucellier cell. Hence by two Peaucellier cells an arm denoted by tan. θ may be, so to say, transferred into an arm tan. 2θ. Thus we see that we may pass through the following series of transformations—

cos. θ, sec. θ, tan. θ, tan. 2θ, sec, 2θ, $\frac{1}{2}$ cos 2θ

—by means of a P. C., a Q. B. E., a pair of P. C.'s, a Q. B. E., and a P. C.—*i. e.*, by an apparatus containing four Peaucellier cells and two cells of the new kind—making a linkage of six cells or 36 links in all. In other words, by means of such a linkage the arm x may be, so to say, converted into $x^2 - \frac{1}{2}$.

If, therefore, by a Q. B. E. we first convert x into the square root $x^2 + \frac{1}{2}$ by superadding to this the linkage last named—*i. e.*, by a linkage of seven cells or 42 links—x becomes converted into x^2. Thus, then, seven cells are required for a squaring or square-root extractor instrument analogous to the cubing or cube-root instrument for which only three cells are required.*

The above investigation leads to a further construction of extraordinary interest, which the speaker is wont to describe as the Kinematical Paradox; every new flight in physics and mathematics, and the same seems equally true of politics, ethics, and philosophy, is apt to commence with a paradox. Two perfect linkages have been described above, one of six, the other of seven cells. Let these linkages both be constructed simultaneously; they will have two detached points of the one (*viz.*, the two extremities of the arm x) coincident with two of the other; their union will itself (according to a general principle) form a perfect linkage. In this linkage of 13 cells two points will lie in the same straight line with the original zero point from which the arms are measured, one at the distance x^2, the other at the distance $x^2 - \frac{1}{2}$

* The much simpler scheme for converting x into x^2, which explains the principle of the cube-root machine, is as follows:

First conversion, $x - \frac{1}{x}$, *i.e.* $\frac{x^2 - 1}{x}$.

Second conversion, $\frac{x}{x^2 - 1} - \frac{1}{x}$, *i.e.* $\frac{1}{x^3 - x}$.

Third conversion, $(x^3 - x) + x$, *i.e.* x^3.

For the trisection of the angle it is necessary to solve Kinematically the equation between cos. 3θ and cos. θ, to effect which it is only necessary to replace the third conversion above by $4(x^3 - x) + x$, *i.e.* $4x^3 - 3x$.

therefrom. Hence there will be two points in this linkage which are disconnected, but in whatever way the other links are drawn in and out, retain an invariable distance from each other. Any other two points of the apparatus may be made to vary their distances from each other, but no force that can be applied at these two points to force them nearer to or separate them further from each other can be of any effect. There is no immediate rigid connection between them, and yet they are as good as rigidly connected. Imagine now that they become connected by a material link; the linkage will not be a fixture, but a perfect linkage as before, consisting, however, of an odd number; *viz.*, 79 links; any one of these may be regarded as a lazy-bar, and may be removed without affecting the motion of which the apparatus is susceptible. Returning to the original state of things, where there are 13 cells, if we fix the two points of invariable distance, the instrument will not become a fixture (as would be the case if any two other disconnected points in it were fixed), but a free link-work with a superfluous or lazy-bar, represented by any of the links at will; for by fixing these particular two points, not *four*, but only *three* degrees of liberty are abstracted. By fixing one of them two such degrees are taken away; but as the other is then not free, but compelled to move in a circle, fixing *it* takes away only one additional degree of liberty of motion.

By this link-work of 78 bars (one supererogatory) a remarkable Kinematical problem has been solved (and it is probably the simplest solution of which it admits), which may be stated as follows: "Required to construct a link-work fixed or centred at two of its points, such that (when the machine is set in motion) some other point or points therein shall be compelled to move in the line of centres."

There are some similar questions to this, which ought, in a strict logical order, to have preceded it, which we may now take into consideration. By a single mounted Peaucellier cell fixed at two centres, one point is made to move perpendicular to the line of centres. Suppose now it were required to devise a link-work such that a point should move parallel to such line.

The motion perpendicular to the line of centres is due to the fact that by the Peaucellier cell the radius vector C cos. θ is transformed into C sec. θ; in like manner to get the parallel direction a means must be found of passing from the cosine to the cosecant. Now although a single cell serves to change the tangent into the secant, or *vice versa*, and consequently a single *imaginary* cell will serve to change the cosine into the sine (which of course could then be immediately Peaucellierized into the cosecant), he is not aware of any direct real process simpler than that about to be stated by which this can be effected. His actual law of deduction is as follows: Cosine; secant; tangent; cotangent; cosecant, involving the use of two Peaucellier cells and two quadratic-binomial extractors.

With one cell more—*i. e.*, with five in all—the cosine becomes converted into the sine, and consequently by introducing a pantigraphic cell cos. θ may be converted into cos. $(\theta + a)$, and this reciprocated into sec. $(\theta + a)$. Thus it seems (at all events after the present method) that four cells are required to obtain by link-work rectilinear motion parallel to the line of centres, and seven cells to convert it into motion oblique to the line of centres; or taking into account the mounting radius 7, 25, 43 links are required to obtain motions respectively perpendicular, parallel, and oblique to that line. In the Kinematical Paradox it will have been seen that there are 13 cells employed; *i. e.*, 78 links, of which any one is liable to removal at will, so that for motion in the very line of centres 77 links are requisite. Consider this system in its entirety. In a straight line with the two fixed points there will be 13 other medial points; and two parallel ranks on both sides, each also containing 13 points. The whole apparatus admits of being moved with a sort of see-saw motion backwards and forwards; and it may assist the imagination of the reader if he will conceive an instrument armed with 13 picks in the line of centres, each at work to remove the asphalt of a pavement under repair; an idea suggested by a member or visitor at a soirée of the amateur Mechanical Society of London, of which the ingenious and accomplished "senior Member for Greenwich" acts as honorary secretary. Or we might describe the Kinematical Paradox as a kind of compound saw. If the "two points of invariable distance" be set free, and some other of the medial points be fixed as a fulcrum, the instrument may be used like Peaucellier's second invention referred to in a previous foot-note as a radial protractor to change the curve

$$p = \text{a given function of } \theta$$

into the curve

$$p + c = \text{the same function of } \theta;$$

as, for instance, to pass from the circle to the Limacon of Pascal, or from a straight line to a conchoid. For while one of the two points of constant distance described any curve, the other would describe the same curve with all its radii vectores reckoned from the fixed point lengthened or shortened by a constant quantity. The Kinematical Paradox ought not to be regarded in the light of a mere luxury of speculation; it serves to represent a constant as a Kinematical function of the independent variable (corresponding to the use of the zero power of x to represent unity in algebra), without which the general analytical theory of linkages, and the very important theory of algebraical functions founded thereon, would fall to the ground, or rather be incapable of being constructed.

It would be difficult to quote any other discovery which opens out such vast and varied horizons as this of Peaucellier—in one direction, as has been shown, descending to the wants of the workshop, the simplification of the steam-engine, the revolutionizing of the millwright's trade, the amelioration of garden-pumps, and other domestic conveniences (the sun of science glorifies all it shines upon), and in the other soaring to the sublimest heights of the most advanced doctrines of modern analysis, lending aid to, and throwing light from a totally unsuspected quarter on the researches of such men as Abel, Rieman, Clebsch, Grassman, and Cayley. Its head towers above the clouds, while its feet plunge into the bowels of the earth.

Prophetic and well-timed were the parting words to the speaker of the illustrious Tchebicheff: "Take to Kinematics; it will repay you; it is more fecund than geometry; it adds a fourth dimension to space." So also said Lagrange.

In the course of the foregoing exposition, incidental reference has been made to the addition of perfect linkages to each other.* This gives rise to the important distinction of all perfect linkages into prime and composite—prime ones being such as can be resolved into the sum of two others, and composite those for which no two such components can be found. As an example of one kind, imagine an octagon with its four pairs of opposite angles (or, which will do as well, its four pairs of opposite sides) connected by links. There will then be 12 links and 16 joints; and since $3 \times 12 - 2.16 = 4$, the linkage will be perfect. Such a linkage is prime, for it will be found impossible to resolve it into two others. Whereas, every cell previously described is capable of being formed by the successive accretions of single pairs of links, thereby justifying in a new and specialized sense the title of Compound Compass, used by Peaucellier to designate his cell. Moreover, cells belong to a very special class of compound linkages, those namely which by successive processes of decomposition can eventually be reduced to depend on sets of link-pairs, and which may accordingly be termed Dyadisms. Dyadisms, again require to be classed according to their order. A dyadism of the first order is one that can be obtained by successive additions of single duads at a time. A dyadism of the second order is one that can be formed by successive additions of single dyadisms of the first order at a time, and so on; and it is very essential to notice that the addition together of two dyadisms of a given order will not in general be a dyadism of the same order. Thus we see that a pure tactical theory of colligation underlies the subject of linkages, a theory of the same nature as that which is known to underlie the doctrine of crystallography and polyhedra; and as that which, under the name of ramification (proposed by the speaker), gives the clearest notion of the modern chemical doctrine of the atom-groupings of the hydrocarbons, and in a manner

* *Viz.*, by pivoting together two disconnected points of the one with two disconnected points of the other, each with each. The sum of two perfect linkages so connected will satisfy the same numerical linear equation between joints and links as its two constituents, and thus will itself constitute a perfect linkage.

supplies an *a priori* ground for the formula of the saturated hydrocarbons C_n. $H_{2n\text{-}1\text{-}2}$, which for the simpler case of the hydroborons (if such series existed), would become C_n $B_{n\text{-}1\text{-}2}$.

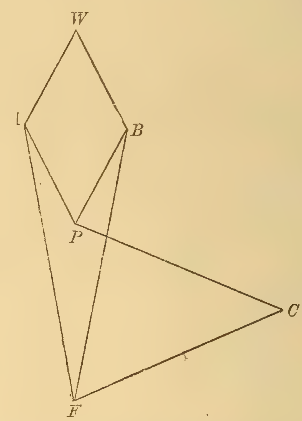
It may be shown that every ramification may be subjected to a process of reduction (a sort of divulsion process, the number of steps of which fixes its genus, or order), which leads eventually to a single intrinsic centre or a pair of intrinsic centres, and consequently may be referred to one or the other of two great classes of forms which may be termed central and axial respectively; and it seems only reasonable to anticipate that the physical properties of such chemical compounds as the hydrocarbons will eventually be found to correspond to this distinction between their representative ramifications; and that they will accordingly arrange themselves under one or the other of two great families distinguished by properties at least as important and specific as those which serve to distinguish the crystalloidal and colloidal states of matter. The theory of ramification is one of pure colligation, for it takes no account of magnitude or position; geometrical lines are used, but have no more real bearing on the matter than those employed in genealogical tables have in explaining the laws of procreation.

The sphere within which any theory of colligation works is not spatial but logical—such theory is concerned exclusively with the necessary laws of antecedence and consequence, or in one word of *connection* in the abstract, or in other terms is a development of the doctrine of the compound parenthesis. M. Camille Jordan, independently of and anteriorly to the author, discovered and published in a memoir, the title of which would never suggest the notion of ramification, the existence of the intrinsic centre and centres here referred to—without having any suspicion of its bearing on modern chemical doctrine. He has moreover discovered the existence of another kind of intrinsic centre of ramification which was unknown to the author of these lines.

A ramification, it ought to be added, is a rootless tree—*i. e.*, one in which the root only ranks the same as the terminal of a branch, and saturated hydrocarbons are typified by ramifications in which every joint is trifurcated, meaning thereby that in tracing the wood outward from any terminal assumed as the root, it splits and splits again, so that trifurcation takes place at each joint, or in other words, *four* lines radiate out from each joint;* the joints are supposed to adumbrate the carbon atoms and the terminal points the hydrogens.

To conclude, as he has begun, with the principal personage of his story, the author thinks it will be useful to several of his readers to have before their eyes the figure which contains the property of the admirable linkage which lies at the root of Peaucellier's conicograph.

In the given figure A P B W is a



rhomb. P A is equal to P B, G P to G F, and G′ is a point lying on F G, or F G produced such that F G′ W is a right angle. Then, however the links are moved about, the motion of W *relative* to F G will be always perpendicular to F G, from which it follows that F G′ W will always continue to be a right angle, and consequently an upright piece attached at G′ perpendicular to F G will always continue to point to W. When W is fixed, the instrument serves as a radial protractor. One point of the upright can describe any curve, and any other point a radial protraction (or retraction) of that curve. When one point of the upright perpendicular is fixed, the combination becomes ideally equivalent to a revolving slot, in which W is free to traverse. The inverse of a conic in respect to a focus (*i. e.*, the Limacon of Pas-

* Observe that if there were *no* splitting, as in a bamboo cane, *two* lines would issue from each joint.

cal) is a protraction or retraction of the circle. Hence the use of the instrument for describing conics.

In the above linkage let a pair of equal links G P, G W be *substituted* for the pair G P, G F. It is easy to prove that if O be the intersection of the diagonals of the rhomb, G O and F O will then be at right angles to each other, and the sum of their squares will be a constant. If now any one link of the rhomb is transferred parallel to itself so as to pass through O, and is jointed on to the sides at the points where it meets them, and O is fixed, and F made to move in a circle containing O, the path of G will be the *inverse in respect to* O *of a conic* of which O is the centre, so that by the aid of a radius and a reciprocator in addition to the transformed linkage above described, a point may be made to move in any conic round its *centre* as a fixed point.* This is rather a simpler construction than Peaucellier's for motion in a conic round the *focus* as a fixed point, for the number of links is no greater, and the ungainly cross-piece disappears. Moreover, it possesses all the advantages of Peaucellier's method arising from the fulcrum lying off the curve to be described. Finally, as regards the most general motion that can be produced by a Peaucellier mounted cell in its generalized form, if F be the junction of two links on which F A, F B are two equal segments, and F C, F D two other equal segments, and P A, P B and W C, W D be two pairs of equal links in the same plane with the first pair, such combination of three pairs is the generalized form of cell in question. In applying it to draw curves, F may be fixed, and a mounting radius of any length attached to P or W, or P or W may be fixed and the mounting radius attached to W or P, or P or W be fixed, and the mounting radius attached to F. In a resumé of this general kind it would be out of place to enter into a discussion of the forms thus generated.

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* It follows as a particular case of the above, that an apparatus of nine links moving round two fixed centres will serve to generate motion in a circle whose centre is in a right line drawn through one of the given two, perpendicular to the line joining it to the other.

Expansion of Ebonite by Heat.—Kohlrausch, having accidentally observed that ebonite lids stick fast in glass vessels, suspected that this material might have a considerable expansibility by heat, and his expectation has been realized by finding that it is about three times as expansible as zinc. This great expansion may possibly be connected with the proportion of sulphur which ebonite contains. On the other hand, the contrast with soft caoutchouc is very remarkable. The increase of the co-efficient of expansion with temperature is very considerable. One fact is mentioned relating to the expansion that seems to be of peculiar value. The bar of ebonite, which was about a centimetre in thickness, after being heated required a considerable time before it assumed a constant length. Although the bad conductivity is doubtless the principal cause of this, the author thinks that another agent also is at work. Like the elastic changes of form, so the expansion by heat may not take place instantly, but continue itself after the change of temperature. A few observations by Matthiesen with glass rods seem to point in this direction. Probably this thermal after-action, like the elastic, occurs in an eminent degree in organic substances.—*English Mechanic.*

Many experiments have been tried in France to test the effects of cold on railway axles. Many engineers suppose that accidents to wheels do not result from any diminution of tenacity of the metal, but merely from its losing all its elasticity, owing to the frost hardening the surface of the earth. A fact which can be adduced as a strong argument in favor of that theory was observed by the inhabitants of Montmartre during the last period of frost. The passing of the trains which run so frequently through the Batignolles tunnel at a distance of half a mile was heard by them day and night, which is never the case in ordinary circumstances. As soon as the thaw set in the trains ceased to be heard; the earth having resumed its former elasticity, the sounds were dissipated as before.

THE NEW METHOD OF "GRAPHICAL STATICS."

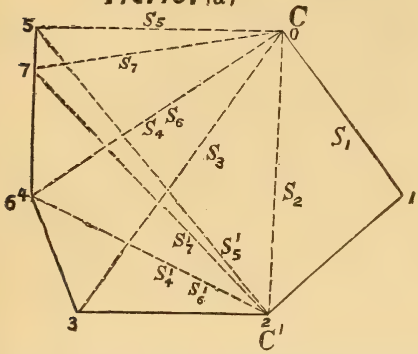
Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

By A. J. DuBois, C. E., Ph. D.

27. MEAN POLYGON OF EQUILIBRIUM.

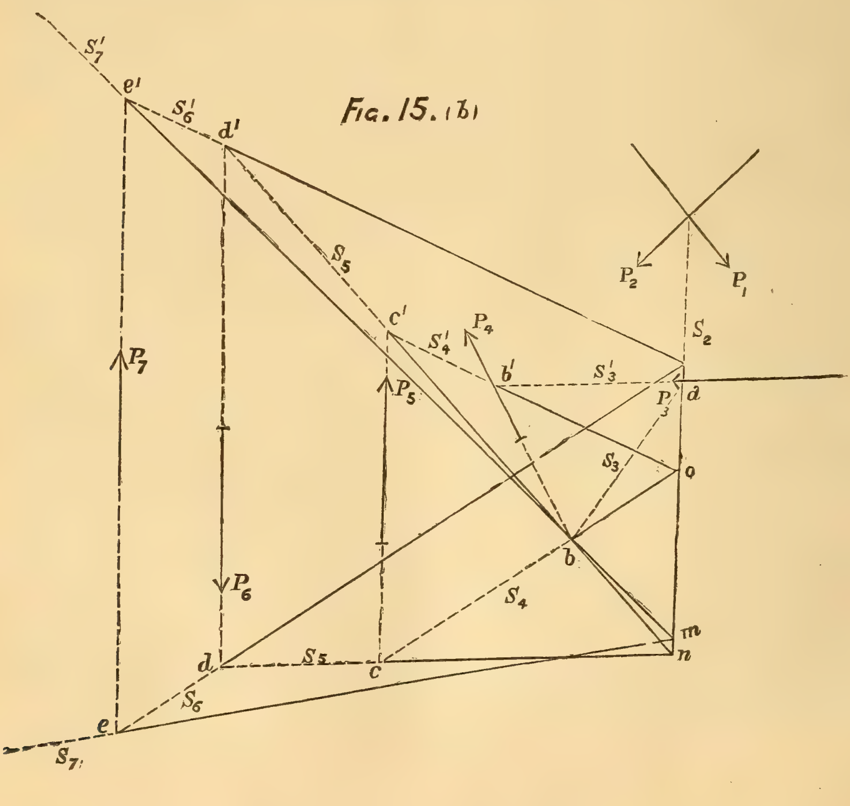
Since the pole may have any position, let us suppose it situated in *one of the angles of* the force polygon. It is evident that the first line of the corresponding equilibrium polygon, then *coincides with the first force.* If now the pole be taken at the *beginning of the first force* in the force polygon, then the first side of the corresponding equilibrium polygon will coincide with the first force, and the last line *will be the resultant itself in proper position.*

Fig. 15. (a)



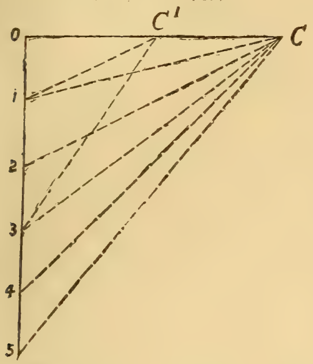
Take for instance, the pole at *o* in the force polygon, Fig. 15 (*a*). The first side S_0 reduces to zero. The next S_1 coincides with 0 1. In (*b*) therefore P_1 is the first side of the equilibrium polygon. The next side S_2 corresponds with S_2 in (*a*). Thus we obtain the polygon *a b c d e*, the last side of which S_7 *is the resultant itself.* That is, S_2 is the resultant of P_1 and P_2, S_3 of $P_{1\text{-}3}$, S_4 of $P_{1\text{-}4}$ and so on. Every line in the polygon then is the resultant of the forces preceding, and we call such a polygon the *mean polygon of equilibrium.*

Fig. 15. (b)



If we wish to find the mean polygon for $P_{3\text{-}7}$ we have only to take the new pole C′ at 2 in the force polygon (*a*). According to

Fig. 16. (a)



the preceding Art., each side of the new polygon must pass through the intersection of the corresponding side of the first with the side S_2 which passes through *a* and is parallel to C C′. Thus S'_4 must pass through *b*′ and *o*. S'_5 through *c*′ and *n*, and so on. S'_7 is the resultant of $P_{3\text{-}7}$, and since S_2 is the resultant of $P_{1\text{-}2}$, S_7, the resultant of $P_{1\text{-}7}$, must pass through the intersection *m* of S'_7 and S_2.

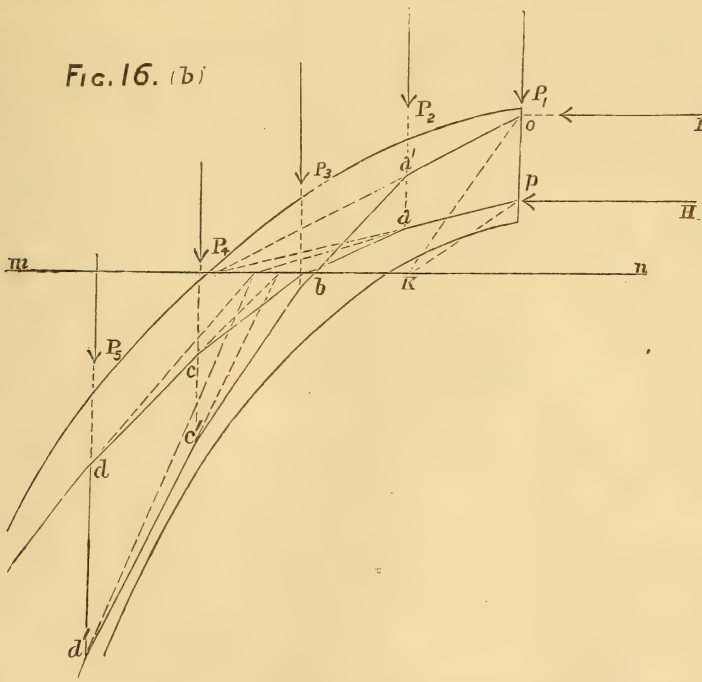
We observe here again the influence of the *couple* P_5 and P_6. S_4 and S_4' are simply *shifted* through certain distances, without change of direction, to S_6 and S_6'; and as we have seen above, knowing the direction of rotation, and the moment of the couple, we might have omitted it in the force polygon and still obtained S_7 and S_7' as before.

28. LINE OF PRESSURES IN AN ARCH.

The practical application of the above will be at once seen in the consideration of an arch.

Thus with the given horizontal thrust applied at a given point of the arch, and

Fig. 16. (b)



the forces $P_{1\text{-}5}$, we construct the force polygon C *o* 5, and then the line of pressures *a b c d*. [Fig. 16.]

Required with another thrust H′=*o* C′ acting at another point, and the same forces $P_{1\text{-}5}$, to construct the corresponding line of pressures. To do this we have only to lay off *o c*′ equal to the new horizontal thrust, then choose a point of the force line, as 3, as a *pole* and draw the corresponding polygon, *k o p k;* the point of intersection, *k*, is a point upon the line *m n* parallel to *o* C, and upon this line will be found the intersection of corresponding sides of the two polygons. Thus from the intersection of the side *a p* of the first polygon with *m n*, draw a line to *o* and we have *a'*. From the intersection *b* of the second line of the first polygon draw a line to *a'*, and we have *b' a'*, and so on.

29. The preceding articles comprise all the most important principles of the Graphical Method which can be deduced independently of its practical applications. Future principles will be best demonstrated, and at the same time illustrated, by considering the various special applications of the method, and to these applications we shall therefore now proceed.

Chapter III.

CENTRE OF GRAVITY.

30. General Method.—One of the most obvious applications of the new method as thus far developed, is to the determination of the *centre of gravity* of areas and solids. We shall confine ourselves to areas only, merely observing that all the principles hitherto developed apply equally well to forces in space. The forces being given by their orthographic projections upon two planes after the manner of descriptive geometry, the projections upon each plane may be dealt with as forces lying in that plane, and thus the projections of the force and equilibrium polygons, the resultant, etc., determined.

A body under the action of gravity may be considered as a body acted upon by parallel forces. The resultant of these forces being found for one position of the body [or the body being considered as fixed, for one common direction of the forces] may have its point of application anywhere in its line of direction.

For a new position of the body [or another direction of the forces] there is another position for the resultant. Among all the points which may be considered as points of application of these two resultants there is *one* which remains unchanged in position, whatever the change in direction of the parallel forces. This point must evidently lie upon *all* the resultants, and is therefore given by the intersection of any two.

It is hardly necessary to give illustrations of the method of procedure.

Generally, we divide up the given area into triangles, trapezoids, rectangles, etc., and reduce the area of each of these figures to a rectangle of assumed base. The heights of these reduced rectangles will then be proportional to the areas, and hence to the force of gravity acting upon them; *i. e.*, to their *weights*. Consider then these heights as forces. Construct the *force polygon* by laying them off one after the other. Choose a pole and draw lines from it to the beginning and end of each force. These lines will give the sides of the *funicular* or equilibrium *polygon*. Anywhere in the plane of the figure, draw a line parallel to the first of these pole lines (S_0). Produce it to intersection with the first force (P_1) prolonged if necessary. From this intersection draw a parallel to the second pole line (S_1), and produce to intersection with second force (P_2). So on to last pole line, which produce to intersection with first pole line. Through this point the resultant must pass, and of course it must be parallel to the forces.

Now suppose the parallel forces all revolved say 90°, the points of application remaining the same. Evidently the new force polygon will be at right angles to the first, as also the new pole lines, each to each. It is unnecessary then to form the new force polygon. The directions of the new pole lines are given by the old, and this is all that is needed.

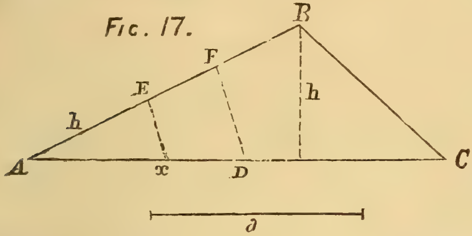
Anywhere then in the plane of the figure, draw a line (S_0') perpendicular to the first pole line (S_0) previously drawn, and prolong to intersection with new direction of first force (P_1'). Through this point draw a perpendicular (S_1') to second pole line, to intersection with new direction of second force (P_2',) and so on. We thus find a point for new resultant, parallel to new force direction. Prolong this resultant to intersection with first and the centre of gravity is determined.

[Note.—If the area given has an *axis of symmetry*, that can of course be taken as one resultant, and it is then only necessary to make one construction in order to find the other.]

The given area of irregular outline must, as remarked above, be divided by parallel sections into areas so small that the outlines of these areas may be considered as practically straight lines. The forces are then taken as acting at the centres of gravity of these areas. This division will give us generally a number of triangles and trapezoids.

It is necessary to reduce graphically to a common base the area of these triangles and trapezoids.

Fig. 17.



32. REDUCTION OF TRIANGLE TO EQUIVALENT RECTANGLE OF GIVEN BASE.

Let b be the base and h the height. Then area $= \frac{b\,h}{2}$. Take a as the given reduction base, and let x represent the height of the equivalent rectangle. Then

$$ax = \frac{b\,h}{2}, \text{ or } \frac{h}{a} = \frac{x}{\frac{1}{2}b}.$$

Now a, b, and h being given, it is required to find x graphically.

Let A B C be the triangle, and D the middle of the base. [Fig. 17.] Lay off A E $= h$ and A F $= a$. Draw F D, and parallel to F D draw E x. Then A x is the required height.

$$\text{For: } \frac{A\,x}{A\,D} = \frac{A\,E}{A\,F} \text{ or } \frac{x}{\frac{1}{2}b} = \frac{h}{a}.$$

As to the *centre of gravity* of the triangle, it is evidently at the intersection of the lines from each apex to the centre of the opposite side ; since these lines are axes of symmetry.

33. REDUCTION OF TRAPEZOID TO EQUIVALENT RECTANGLE.

In the trapezoid A B C D, Fig. 18, draw through the middle points of A D and B C perpendiculars to D C, and produce to intersections E and F with A B produced.

Then lay off F $g = a =$ the given reduction base, and draw g E intersecting D C in x. Then H x is the required height.

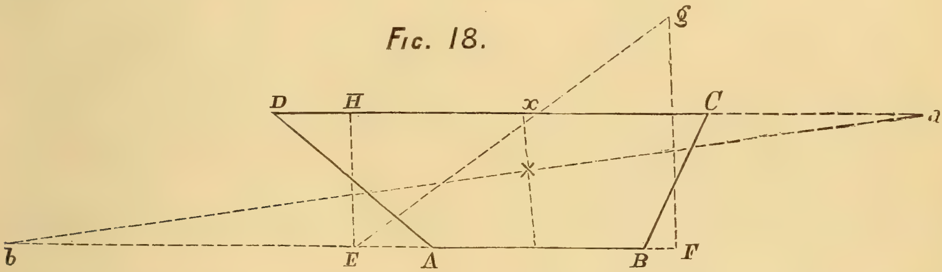
$$\text{For } \frac{E\,F}{F\,G} = \frac{H\,x}{H\,E} \text{ or } \frac{E\,F}{a} = \frac{x}{H\,E};$$

hence $a\,x = E\,F \times H\,E =$ area.

To find the *centre of gravity*, draw a line through the middle points of the parallel sides A B and D C. This line is an axis of symmetry. Prolong A B and C D and make C $a =$ A B and E $b =$ C D and join a and b. Then the intersection of $a\,b$ with the axis of symmetry gives the centre of gravity.

The construction for the reduction of a *parallelogram* is precisely similar. [Fig. 18 (b).]

Fig. 18.

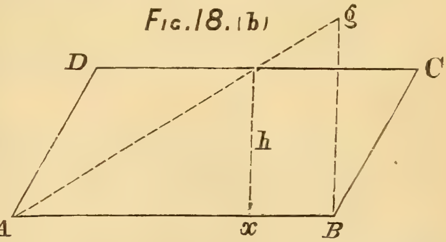


The points F and E here coincide with A and B, and we have

$$\frac{A\,x}{h} = \frac{A\,B}{B\,g}, \text{ or } a\,x = h \times A\,B = \text{area}.$$

The same construction also holds good, of course, for a *rectangle* or square. The centre of gravity in each case is at the intersection of two diagonals, since these are axes of symmetry.

Fig. 18. (b)



34. REDUCTION OF QUADRILATERAL GENERALLY.

In general any quadrilateral may be divided into two triangles which may be reduced separately, or into a triangle and trapezoid.

It is also easy to reduce any quadrilateral to an *equivalent triangle*, which may

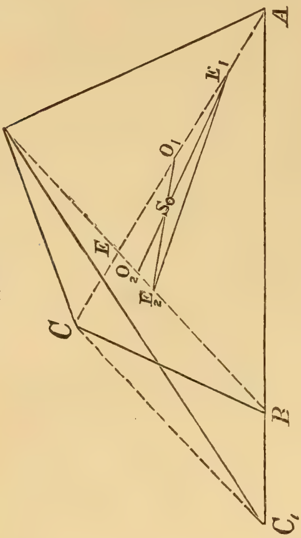


Fig. 18. (c)

then be reduced by Art. 32 to an equivalent rectangle of given base.

Thus we reduce the quadrilateral A B C D [Fig. 18 (*c*)] to an equivalent triangle by drawing C C_1 parallel to D B to intersection C_1 with A B, and joining C_1 and D. The triangle D B C_1 is then equal to D B C, and hence the area A D C_1 is equal to A B C D. The triangle A D C_1 can now be reduced to an equivalent rectangle of given base by Art. 32.

The *centre of gravity* of the quadrilateral may be found as follows:

Draw the diagonals A C and B D and mark the intersection E. Make A E_1 = C E and B E_2 = D E, also find the centres O_1 and O_2 of the diagonals A C and B D. Join O_2 E_1 and O_1 E_2; the intersection S of these two lines is the centre of gravity required.

The above is sufficient to enable us to find the centre of gravity of any given area of regular or irregular outline. The method may be applied to finding the centre of gravity of a loaded water wheel (as given in Reuleux, *Der Constructeur*, Art. 47), and many similar problems. The reader will have no difficulty, following the general method indicated in Art. 30, in making such applications for himself. The method itself is so simple that it is unnecessary to give here any practical examples in illustration. We shall, moreover, have occasion to return to the subject in the consideration of *moment of inertia of areas.*

We pass on therefore to the *moment of rotation of forces in a plane.*

Chapter IV.

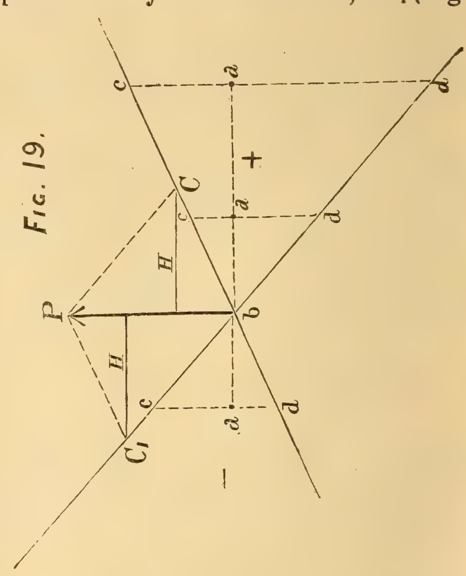
MOMENT OF ROTATION OF FORCES IN THE SAME PLANE.

35. The "moment" of a force about any point is the product of the force into the perpendicular distance from that point to the line of direction of the force. The importance and application of the "*moment*" in the determination of the strains in the various pieces of any structure will be evident by referring to Art. 14, where Ritter's "method of sections" is alluded to. In general, when the moments of all the exterior forces acting upon a framed structure are known, the interior forces, or the strains in the various pieces, can be easily ascertained.

As we shall immediately see, these moments are given directly in any case by the "*equilibrium polygon.*"

36. CULMANN'S PRINCIPLE.

If a force P be resolved into two components in any directions as *b* C, *b* C_1 (Fig.



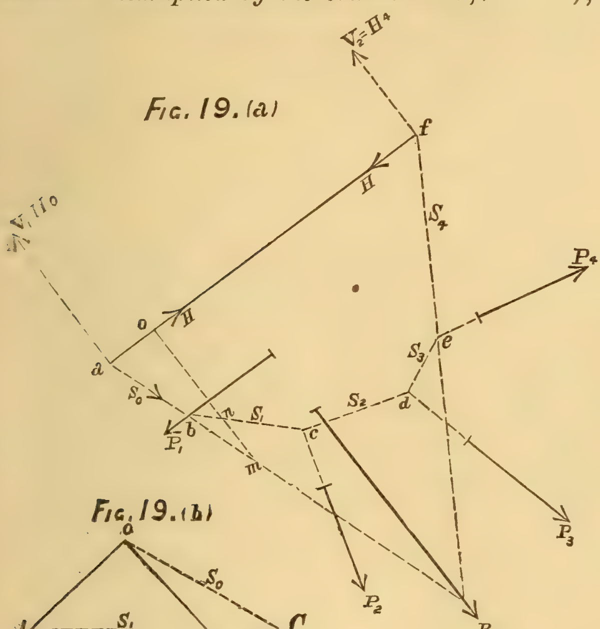
19), and these components be prolonged, it is evident that the *moment* of P with reference to any point as *a* situated anywhere in the line $c\,d$ parallel to P is $P \times b\,a$. But if from C we draw the perpendicular H to P, then by similar triangles,

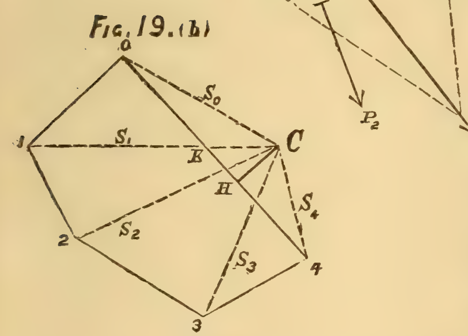
$$P : H :: cd : ba;$$

or

$$P \times b\,a = H \times c\,d.$$

That is, *the moment of* P *with respect to any point a is equal to a certain constant* H *multiplied by the ordinate c d,*





parallel to P *and limited by the components prolonged.* The constant H we call the "*pole distance.*"

This holds good for any point whatever, and we have only to remember that if we assume the ordinates to the right of P as positive, those to the left are negative.

We can choose the *pole* C where we please, and thus obtain various values for H, but *for any one value the corresponding ordinates are proportional to the moments.*

The above principle is due to *Culmann,* and will be referred to hereafter as *Culmann's principle.*

37. APPLICATION OF THE ABOVE TO EQUILIBRIUM POLYGON.

Let $P_{1\text{-}4}$ be a number of forces given in position as represented in Fig 19 (*a*). By forming the *force* polygon Fig. 19 (*b*), choosing a pole C, and drawing S_0, S_1, S_2, etc., we form the *equilibrium polygon a b c d e f*, Fig. 19 (*a*).

The resultant of the forces $P_{1\text{-}4}$ acts in the position and direction given in the Fig. Now, as we have seen in Art. 22, regarding the broken line *a b c d e* as a system of *strings,* we may produce equilibrium by joining any two points as *a* and *f* by a *line*, and applying at *a* and *f* the forces S_0 and S_4. Let us suppose this line *a f* perpendicular to the direction of the resultant. Since we can suppose the broken line or polygon fastened at any two points we please, this is allowable, and does not affect the generality of our conclusion.

Then the compression in the line *a f* is given by H, the "*pole distance,*" or the distance of the pole C from the resultant in the force polygon. We have therefore at *a* the force H and $V_1 = H\,o$ acting as indicated by the arrows. At *a* then V_1 acting up, H and S_0 acting away from *a*, are in equilibrium, or V_1 is decomposed into H and S_0, as shown by the *force polygon.*

According to *Culmann's principle* then, the moment of V_1 with reference to any point, as *m* or *o*, is equal to $H \times o\,m$. Therefore H being known, the ordinates between *a f* and S_0 are proportional to the moment of V_1 at any point. V_1 acting upwards gives positive rotation (left to right) with respect to *m*.

At the point *b*, P_1 may be replaced by a force *o* K parallel to R and a force K 1 along S_1 [see force polygon]. This we see at once from the force polygon where *o* K and K 1 make a closed polygon with P_1, and taken as acting from *o* to K and K to 1, *replace* P_1. But these two forces are in equilibrium with S_1 and S_0 or 1 C and C *o* [see force polygon], and since K 1 and 1 K balance each other, all the forces acting at *b* may be replaced by S_0 *o* K and K C. We have then at *b* the force O K resolved into components in the directions S_0 and S_1.

By *Culmann's principle*, therefore, the moment of O K about any point as *m*, is proportional to the ordinate *n m*, and since O K acts downward this moment is negative. Hence the *resultant* moment at *m* or *o* of the components at *a* and *b* parallel to R, is proportional to the ordinate *o n*.

So for any *point*, *the ordinate included by the polygon a b c d e f, and the closing line a f, to the scale of length multiplied by the "pole distance"* H *to the scale of force, gives the moment at that point of the components parallel to the resultant.*

The practical importance and application of this principle will appear more clearly in the consideration of parallel forces in the next chapter.

OIL FUEL.

From "Iron."

The fuel question, in all its bearings, is one of which the importance can be hardly overestimated by a people so essentially industrial as ourselves, and least of all by a generation which has witnessed the violent and disastrous fluctuations in value to which our staple fuel has been recently subject. It behooves alike the man of science and the practical engineer to be unremitting in their endeavors to discover some practicable substitute for the dominant black diamond, or we may witness before long (however improbable it seems to-day) a renewal, in an even more acute form, of a coal crisis, with its accompanying disarrangements of industry and commerce. A few repetitions of such crises could hardly fail to pave the way for that downfall of our industrial supremacy, and indeed our political status, which it hardly needs a Cassandra to predict, would follow, if it did not anticipate, the exhaustion of our coal-measures. Whether that exhaustion be comparatively imminent, or in the remote future, we will not now discuss, though the grounds on which opinion on this subject were formed both by the royal commission and independent writers, some years ago, have been shown by the course of events to have been inadequate.

The list of possible substitutes for coal is by no means a long one, and chemistry and geology alike forbid our entertaining any hopes of their number being increased. Wood and peat, lignites and tertiary coal, form, with mineral oils, the only natural substances existing in sufficient abundance to be of any real service as heat generators. The destruction of forests throughout the world is progressing at too rapid a rate to allow of dependence on wood for any substantial relief. The utilization of peat, prepared by some of the methods now in operation on the Continent, is more promising as regards those localities in which it is plentiful, but its calorific value is not sufficiently high, nor does it exist in sufficient abundance, to enable it to bear the expense of carriage or be of anything more than local value. The lignites and inferior descriptions of coal will probably find an extended application for metallurgical and steam-raising purposes as gas-producers in regenerative furnaces (in which also peat might be economically used), but these substances exist only in very limited quantities in the British islands, and the European deposits are not sufficiently extensive to admit of exportation.

The only substances we have remaining consist of the mineral oil group, and it is to them we propose to draw attention, as possessing, when properly applied, many of the characters of an ideal fuel.

On this subject a little book, entitled "Air as Fuel," has been written by Mr. Owen Ross, to which we are indebted for many interesting facts. The title, indeed, is suggestive of either a blunder or a paradox, but on reflection may be allowed to be neither. The fact is we have grown so accustomed to the conventional use of the terms *combustible* and *supporter of combustion*, the latter term being exclusively applied to oxygen, as to regard them as indicating specifically distinct properties, the power of supporting combustion being peculiar to oxygen. But if we consider that the term combustion is applicable to any chemical action sufficiently energetic in character to give rise to the phenomena of light and heat, and that we may, for instance, with equal propriety regard hydrogen as supporting the combustion of oxygen as the reverse, it may be admitted that air, in virtue of its oxygen, is essentially a fuel. It might, however, be questioned if the title quoted be not a misnomer for a work advocating the use of volatile hydrocarbons, did not the value of its contents indispose one to mere verbal criticism.

We may first consider whether mineral oils exist in sufficient abundance to justify our looking on them as capable of supplying an important part in the world's fuel-supply. These oils are found both in the free state, stored in vast subterranean reservoirs, such as those which once tapped became and still are a perennial source of untold wealth to the lucky landowners of Pennsylvania and Ohio, and also in a less accessible form, saturating enormous deposits of shale, bitumen, or bituminous limestone. Under various names—such as petroleum, naphtha, mineral pitch, rock oil, or bitumen—these products and their derivatives are to be found in every quarter of the globe. In Canada and the States, Germany and Australia, the East Indies and the West, on the shores of the Caspian, and in the jungles of Burmah; in these and a score of other localities, including our own country, there have been already discovered, in some shape or other, oil-bearing rocks or bituminous shales, and that too in such abundance as to promise, for some generations at least, a practically inexhaustible supply. The production of the United States alone for last year was little short of 300,000,000 gallons, or considerably over 1,000,000 tons, of which about one-half is exported to Europe. It is evident that we have here a class of substances which for general diffusion and abundance fulfil every requirement. But are they capable of being advantageously used as a fuel? The practical results already obtained with inefficient means seem to confirm the affirmative answer which theory would give to this query.

It may be assumed that the only two elements which are of value as combustibles are hydrogen and carbon; and the value of any fuel will vary according to the proportion these two bodies bear to each other, and the amount of foreign or neutral substances mixed with them. The approximate calorific value of carbon has been ascertained to be 8,080 calories, or in other words, a unit weight of carbon burnt to CO_2 would raise 8,080 units of water 1 deg. C. in temperature, if the entirety of the heat generated could be expended on the water. The calorific value of hydrogen would, in the same way, be represented by 34,260 calories; or we may equally well express the fact by saying that the combustion of a given weight of these bodies would convert 14.6 and 62.5 times that weight of water at 100 deg. into steam. When, however, we take into consideration the respective volumes and specific heats of the products of combustion, these results are considerably modified, carbon becoming, especially for metallurgical purposes, where concentrated and intense heat is required, very superior to hydrogen in value. The composition of a good coal may be assumed as 76 to 92 per cent. carbon, 3 to 5 per cent. hydrogen, and from 3 to 10 per cent. oxygen, with about 3.5 per cent. of ash. We have here the ash and oxygen playing no part in the production of heat, while the oxygen, in addition, neutralizes the heat potential of a quantity of hydrogen equal to one-eighth of its own weight. Making due allowance for ash and oxygen, the theoretical evaporative effect of a good average coal may be taken as 14.5.

It is also recognized that the absolute practical effect of any given fuel will always be very inferior to its theoretical value, owing chiefly to imperfect combustion and to excessive dilution of the products of combustion with unburnt air, but being in part due to imperfect abstraction of heat from those products, and losses by radiation and conduction. Thus an elaborately organized series of experiments, carried on over a considerable period on behalf of the Admiralty, established that even under the most favorable circumstances the maximum effect obtainable from one pound of the best steam coal was the evaporation of 9.5 lbs. of water, while ordinary qualities would scarcely evaporate 8 lbs. It therefore appears that two-thirds of the theoretical duty is more than can be reckoned on in actual working; the one-third loss being chiefly attributable to imperfect combustion and excess of air admission. In metallurgical furnaces the loss is frequently as much as 95 per cent. of the total heat generated.

It is by no means an easy matter to define chemically the constitution of mineral oil; not only do different localities produce oils of varying characters, but chemists are by no means unanimous in their classification. The fact is, the liquids we call petroleum and naphtha are mixtures of a number of distinct hydrocarbons, chiefly of the homologues of marsh gas (of which twelve have been already isolated), each having a different boiling point, which permits of their separation by fractional distillation.

When heated, the gases hydride of ethyl and hydride of propyl are readily given off, these bodies being gases even at 1 deg. C. The boiling points of the remaining members of the series range between 4 deg. and 260 deg. Besides these marsh gas homologues, there are present other oils of a still higher boiling point. With regard to its percentage composition we can be more definite; analyses of crude oils from America and Persia, Europe and Burmah, vary but slightly from an average of 84 per cent. carbon, 13 or 14 per cent. hydrogen, and 2 per cent. oxygen. The distilled oils, however, give a much smaller percentage of carbon, with a correspondingly increased proportion of hydrogen. The calorific power of one of these distillates which boils at 126 deg. Fahr., calculated from its composition, as given by Pelouze and Cahours, viz., 71.7 per cent. carbon and 28.2 per cent. hydrogen, would equal 15,460 heat units, or an evaporative effect of about 28 against 14.9 for the best coal. Thus, the theoretical value of this volatile oil is nearly double that of the best coal. A crude petroleum with 85 per cent. of carbon would give a theoretical evaporative effect of about eighteen units.

Thus far theory: as regards the practical application we have as yet unfortunately a lack of sufficient data, but we will collect what we have and examine their bearing by such light as theory and analogy will afford. In 1866 and 1867 a series of experiments were made at Woolwich with several varieties of oil, with the view of ascertaining their applicability for use in the navy. The result of these experiments, in which the oil was mixed with steam jets with the idea of assisting its combustion, was to prove that the average evaporative effect was about 13 lbs. evaporated, with 1 lb. of oil. It should be observed here that in many of the trials much soot and smoke was produced, a circumstance which shows that the fuel was imperfectly consumed, and which would also impede the transmission of heat to the water. The maximum effect obtained was an evaporation of 18 lbs. At about the same time liquid fuel was put on its trial in France, where the furnaces of two locomotives on the railway between Paris and Strassbourg were adapted to the consumption of oil, and were wholly fed with that fuel for a period of two years. The attempt was finally abandoned on an adverse report by Deville—though no fault appears to have been found with the efficiency of the engines—on account of the high price then ruling for petroleum. At intervals the introduction of liquid fuel has been tried on an Imperial yacht, some Russian steamers on the Caspian, and in the American navy, but always with indifferent success. In each case complaints are made of an excessive amount of smoke being produced, and a tendency in the boiler-tubes to become choked with soot.

Are these failures to be accepted as conclusive against the employment of any fuel but coal or its gases? In the first place, we have against these unsatisfactory results the fact that tar-oils have been used, either alone or in conjunction with other fuel, with perfect commercial success in many English factories for boiler furnaces; while petroleum, in America, has also, in private hands, met with an extended application. Moreover, in the United States, an oil metallurgy is being rapidly brought into a practical shape, and has indeed passed beyond the merely tentative stage. But the real issue remains—were the unsuccessful trials carried out under conditions in which success might have been reasonably anticipated? It is to be remembered that the fact of soot being produced in notable quantity is conclusive evidence of imperfect combustion, and therefore of bad arrangements. We all know the difference between a lamp so ill-constructed as to have a bad supply of air with a necessarily smoky and wasteful flame, and another which, receiving an adequate stream of oxygen, burns without a particle of smoke. Just so with a furnace; we are aware that contact with the surface of the boiler has a tendency so to cool the flame as to impede perfect combustion, but, on the other hand, as we do not require a luminous flame in a furnace, an increased admittance of air should compensate for this. Again, a steam jet is the worst possible means of promoting the combustion of the oil, as it must necessarily abstract a considerable portion of heat from the flame, and yet give no aid to combustion, other than by scattering the liquid into a spray. If used at all, the steam should be super-heated to about 1,000 deg. C., as has been done in a successful tar-burning furnace in the States. It would also appear from the excessive difference between the maximum and minimum evaporative effects obtained (which are represented by seven and eighteen units respectively) that there was much room for improvement, had the trials been continued and the apparatus modified.

We have seen that the theoretical evaporative value of liquid hydrocarbons ranges between eighteen and twenty-seven units; taking twenty-two units as an average, we should expect a useful effect of not less than twenty units, since the causes which induce the excessive waste characterizing solid fuels are here almost entirely absent. In confirmation of this opinion, it may be mentioned that Professor Rankine, who devoted considerable attention to this subject, was definitely of opinion that nine-tenths of the theoretical efficiency might be looked for with hydrocarbon liquids as fuels. With a coal-burning furnace, it is requisite to pass at least double the quantity of air through the grate that would suffice for the chemical requirements of combustion, the surplus carrying to waste about 1,200 heat units; yet even with this enormous volume of air, perfect combustion is not attained. Now, by passing a current of air over the surface of a moderately volatile oil, boiling at about 126 deg. Fahr., we should obtain air so saturated with vapor as to be highly inflammable, and by properly proportioning the surface of oil exposed and its temperature to the volume of air, we can obtain a mixture in which the oxygen of the air shall be in any desired ratio to the elements of the fuel. It is proposed to use a fan to produce this air current, but it is probable that the draught from the stack would be amply sufficient for the purpose. The obvious advantage of a system which would allow of fuel being consumed, with the aid of but a trifle more than the bulk of air sufficient to yield the oxygen required for the chemical exigencies of combustion, need hardly be insisted on. It would afford, on a large scale, the results which on a small one are yielded by the Bunsen burner; in fact, it would be impossible to devise conditions more favorable to complete combustion with a minimum of air. Add to this that oil has no ash, and that, as the carbon is already in a state of vapor, we have not the absorption of heat due to this cause—against which is to be set a slight and problematical loss attending the decomposition of the union between the hydrogen and carbon—and it seems a moderate estimate to assume for a mineral oil, costing in London about £8 10s. or £9 a ton, an evaporative power of about 20 or 21. In metallurgical furnaces it is not possible to fix the exact efficiency of hydro-carburetted air, but, as we have here to deal with very high temperatures, the proportional saving resulting from a limitation of the air-supply, combined with perfect combustion, would be far greater than in steam raising, while the margin for economy, even with regenerative furnaces, is enormous.

Mr. Ross, unfortunately, indulges in rather exaggerated statements in support of his views, as when he asserts that 1 lb. of a light oil will evaporate 28 lbs. of water, a result purely imaginary. With this caution his arguments may be recommended to the attention of fuel-consumers, and particularly to metallurgists and ship owners. Granting to oil the evaporative efficiency of twenty-one units, an ocean steamer burning oil might hand over more than two-thirds of her bunker room to cargo, since a ton of oil occupies only 34 cubic feet, as against 43 cubic feet for a ton of coal. In situations where space is limited, coal costly, or intense heat required, it is likely enough that the patent advantages of a liquid fuel will render it a formidable rival to that tyrant coal, which, more than gold or silver or any other substance, controls the destinies of races.

THE BLOCK SYSTEM FOR RAILWAYS.*

From "The Review of Mining."

THE object of the block-system is to prevent collisions of the trains which follow each other on the same line.

In Belgium, up to this day, on lines worked by the State, as on those belonging to private companies, the distance at which trains follow each other has been regulated by time. On the State lines, a train can only leave a station five minutes after the departure of the preceding train in the same direction. This interval is reduced to two minutes for sections of three kilometres and less in length, common to different lines.

These regulations are attended with serious inconveniences. In fact, it is very difficult, for many reasons, to keep up on the line, this interval of five minutes between the passage of two trains at the same points. Among these reasons, we may instance the difference in the load of the two trains, a sudden diminution of the tractive power of one of the locomotives, the inattention or negligence of the servants of the line whose duty it is to maintain this interval by means of the signals, etc.

If the first train happens to stop at a place where it is not covered by fixed signals, which occurs frequently at the approach to stations, when the traffic is considerable, and sometimes on the open line, after an accident, the result is, that the chances of a collision are sufficiently great, if a curve in the line, a fog, or snow, prevents the driver of the second train from seeing the first at the necessary distance for ensuring its stoppage in time. True, the regulations prescribe that the guard of a train that has stopped should go back immediately 700 centimetres to make stop signals, but this measure is very rarely put in practice.

In fact, when a train is kept back by a distance signal which blocks the entry to a station, the guard is uncertain as to whether he should not immediately go forward; in case of an accident, it can be easily understood that, during the first moment which follows a catastrophe, the officials, when they are safe and sound, occupy themselves first of all with the passengers, and never think of preventing the arrival of the following train.

Even when a train is protected by distance signals, fog, snow, and the extinction of the signal light during the night, may bring about collisions. They may also arise from negligence in the working of the signals, or from some irregularity in the apparatus.

This rapid glance will show that the interval of time does not afford sufficient security, when the traffic is very active. For a long time, means have been sought to prevent collisions; that which appears to be the most efficacious is to displace the interval of time by an interval of distance. This constitutes the block system.

By this system, the line is divided into sections, and it is laid down as a principle that two trains which follow each other are not to run at the same time, on the same section. A station, therefore, cannot dispatch a train until it has received advice that the preceding train has reached the appointed spot.

The length of the sections being, on an average, from 2 to 3 kilometres ($1\frac{1}{2}$ to 2 miles), the advices are sent by electrici-

* From a paper read before the Association of Engineers at Brussels, by F. Defarge, Engineer of Belgian Railways.

ty. As regards the apparatus used for this purpose, they may be of any system; on the Morse system, for example.

It is evident, however, that the guarantee is so much the greater when the apparatus is the least subject to error.

A telegraph apparatus must necessarily be placed at the end of each section.

Their lengths depend on the number of trains which have to pass in a given time. Suppose that the necessities of working are such, that trains have to be dispatched from a station at an interval of two minutes; the first apparatus which defines the limits of the first section, must be placed at such a distance, that in two minutes the first train must have arrived there. Instead, then, of the *block system* being a cause of the diminution of the traffic, it admits of its increase, while providing almost perfect security.

If the stations are near to each other, and the traffic unimportant, each section may be composed of the whole interval comprised between the two stations.

The first application of the block system belongs to a comparatively distant date. The working of the first railway commenced in England in 1829, by the Liverpool and Manchester line. At the beginning, no signal was used. The first distance signal was erected in England, whence it was introduced into France.

In 1843, W. F. Cooke, an English engineer, established the following principles for the working of railways:

"Every point of the line is a dangerous point, which ought to be covered by distance signals.

"The whole distance, consequently, ought to be divided into sections, and at the end, as well as at the beginning of them, there ought to be a distance signal, by means of which the entrance to the section is opened to each train, when we are sure that it is free, and may be passed over, exactly as if each section were a station, or bifurcation. As these sections are too long to be worked by a traction rod they ought to be worked by electricity.

"At the end of each section of from 2 to 2½ English miles, a line-keeper is stationed in a hut, with a turning disc, or semaphore.

"In each hut there ought to be two telegraphs with magnetic needles, the one on the right hand being in communication with that on the left of the neighboring hut.

"The needle telegraph can only give two signals: *line clear*, or *line blocked.*

"All the semaphores belonging to the section ought to be set at stop."

These are the principles of the block system.

Cooke's apparatus was first used on the Eastern Counties Railway, between Yarmouth and Norwich.

Unfortunately, the arrangement which was adopted in practice was a complicated one. Many railway companies modified the idea of Cooke, in using the single-needle telegraph.

These arrangements, more or less complete, not having prevented accidents from happening, a discussion arose among English engineers, some pretending that the use of electricity ought to be proscribed from railways, because it was dangerous, while others held the contrary opinion. Mark Huish, who published several works against the use of electricity, invented in 1863 the staff system, which consists of dividing the line into sections, as in the block system, giving to each of them a single staff of a special color, with which the engine-driver was to be provided before entering upon the section.

The staff, then, acts as a pilot. This system was, it appears, employed in America in 1867 on the greater part of the single rail lines.

In spite of the opposition to the extension of electric signals, 250 miles of railway were furnished with them in 1845, and 500 miles in 1846. Shortly after the Board of Trade decided that every line on which more than one locomotive was employed, should be furnished with them.

The first improvement on Cooke's idea was made by M. E. Clarke, Stephenson's successor. This engineer laid down as the principles of the application of the block system:

"That the apparatus ought to be as simple as possible, and little subject to derangement.

"That the signals should be single, few in number, and clear enough to prevent error.

"That the memories of the workpeople should be as little taxed as possible, and that the signals, consequently, ought to be permanent and not temporary; in fact, that no accident ought to be possible by the derangement of the apparatus, or the absence of the line-keeper, but that these irregularities should only cause a delay of the trains at the most."

Clarke constructed an apparatus embracing, as much as possible, the above conditions. Other arrangements were conceived soon after by Walker, Tyer, Bartholomew, Preece, and Spagnoletti, and were applied on different lines.

With all these apparatus, the following is the course adopted. The station wishing to dispatch a train, informs the post towards which it is directed, by means of a small electric bell; alone, or combined with a magnetic needle, or by small levers, representing the arms of a semaphore. If this post is certain that no train is upon the section, it gives the order of departure by a signal analogous to the above. Walker's system, which, however, only consists in the transitory tingling of bells, has been at work eleven years on the South Eastern railway, on a length of five miles, leading out of London, without there having been a single accident, notwithstanding a daily average traffic of 196 trains.

At present the *block system* is in use on about a fourth part of the lines in the United Kingdom. As the journals have reported, a special commission of the House of Commons, which has been recently appointed to consider the means of diminishing the number of railway accidents, is of opinion that the block system is the best adapted for that purpose. Nevertheless, this commission has expressed the opinion that there was no reason for enforcing it upon the railway companies, because they will end by adopting it of their own accord, in consequence of the pecuniary advantages to be derived from its use. The block system is in force on some lines in France. Tyer's apparatus has been adopted by the Paris-Lyons and Paris-Strasbourg companies. The Nord-Francais has just decided to adopt Lartigue and Tesse's apparatus, lately invented, on its lines.

In Germany, a law decreed the enforcement of the block system on all lines, commencing on the 1st of January, 1872.

Lastly, the administration of the Belgian state railway proposes to apply it to all the principal lines. The first trial will be made on the section from Melle to Ostend. The apparatus fixed upon is that of Siemens and Halske, of Berlin.

It is to be observed that the block system has been in use some time on the state lines, at the Halinsart and Gemmenich tunnels, as well as on the lines from Pieton to Leval, and from Baume to Marchienne; but, as its application was the result of entirely exceptional circumstances, it has not been made general.

The general arrangement of Siemens' and Halske's apparatus is the following:

Let there be three posts, A, B, C. Each has a two-armed semaphore, with a lantern, comprising a cast-iron box, pierced with two windows, before each of which is a disc. One of the discs, and one of the arms of the semaphore, correspond with the course of the trains in one sense, and the two others to their course in an inverse sense.

The cast-iron case being generally placed in the hut of the line-keeper, the engine-drivers have only to attend to the position of the arms of the semaphore. Each of the discs appear in red or white according as the line is clear or blocked.

Shortly before the passage of the train the arms of the semaphores are placed in the position of *line free*. When the train has passed the post A, it puts its semaphore at *stop*, and its disc at red. The train then is covered. Having arrived at B, and passed the semaphore at this post, the latter acts in like manner at A, and by the manœuvre which it executes to bring back its own disc to red, it sends out currents which change A's red disc into white. A second train can then start from A towards B. The first train having arrived at C, this last, as we have just said, brings the red disc of B to white, etc., etc. The guarantees for security which these apparatus give are the result of the following arrangements:

1. The movements of the discs are caused by currents of induction, alternately positive and negative; a contact between the aerial thread which does the office of these apparatus, and an ordinary telegraphic wire, has no influence on this movement. It is the same with discharges of atmospheric electricity (a storm, etc.)

2. No post can send currents which

bring to white the disc of the preceding post, without having put its semaphore to *stop*.

No post, A for example, can make its semaphore pass from the position of *stop* to that of *clear*, before the next post, B, has announced the arrival of the train, by changing into white, as has been said, the red disc of A. Any post can make its disc pass from white to red, but it cannot change its red disc to white, and it cannot change its position of *stop*, by the arms of the semaphore, as long as its own disc is red. It results, then, from the above two points, that it is only the post where the train has arrived which can clear the way for the preceding post, and that it can only perform this manœuvre after having itself covered the train. The conclusion of this is that *each train is necessarily always covered by the semaphore of a post.* This capital advantage constitutes the superiority of Siemens's apparatus over those used in England. In the latter there is no solidarity between the semaphores which command the line and the apparatus which receive the electric signals, nor between the apparatus of the different posts. It follows that any negligence on the part of those whose duty it is to work them, may be attended with serious consequences.

In the apparatus which he makes now, Mr. Siemens affixes a commutator, which permits, when the train is in sight, to announce the fact to the following post, by means of the same line wire, and a small special bell. Besides, a second ring of a bell placed in the interior of the cast-metal case, acts every time the discs are put in movement, by electric currents. Siemens and Halske's apparatus are well made. According to the engineers on the lines where they are used, their working is regular, they are little subject to derangement, and are maintained at small cost. When one ceases to work, from a rupture of a wire, or from any other cause, the service is performed on a defective section, unless other means of communication are adopted, in a manner analogous to what takes place now on our lines.

The expenses of fitting-up vary with the local conditions of each line.

In Belgium, on the section from Melle to Ostend, they amount on an average to 763 fr. per kilometre, all expenses of furnishing and workmanship included. On the open line, the sections will consist of about 3 kilometres. For a system of about 1,000 kilometres, the entire cost of fitting would be 763,000 fr. The annual cost of interest and amortisement of this sum may be fixed at 49,710 fr., allowing an average duration of thirty years for the apparatus, semaphores, etc. It is sufficient that a few collisions be avoided, in order that the expenses of the apparatus may be largely covered. In fact, the damage arising out of an accident may easily amount to from 30,000 fr. to 40,000 fr., without counting the indemnities to be paid to the families of the victims.

In England, the damages paid by the various railway companies have reached, in five years, the amount of sixty millions, or twelve millions annually.

These economical considerations have their value, because they prove that the use of the block system is not so onerous as might at first be believed; but humanity demands its adoption as the most efficacious means of insuring the lives of the passengers.

Among the many vegetable products of Brazil the pottery tree of Para is not the least worthy of note. This tree, the *Moquileautilis* of botanists, attains a height of 100 ft. up to the lowest branches. The stem is very slender, seldom much exceeding 1 ft. in diameter at the base. The wood is very hard and contains a very large amount of silica—not so much, however, as the bark, which is largely employed as a source of silica in the manufacture of pottery. In preparing the bark for the potter's use it is first burned, and the residue is then pulverized and mixed with clay in varying proportions. With an equal quantity of the two ingredients a superior quality of ware is produced. It is very durable and will bear almost any amount of heat. The natives employ it for all manner of culinary purposes. When fresh the bark cuts like soft sandstone, and the presence of the silex may be readily ascertained by grinding a piece of the bark between the teeth. When dry it is generally brittle, though sometimes hard to break. —*Engineering.*

PERMANENT WAY.

From "Engineering."

Could Professor Crookes, Mr. Varley, or some other F. R. S. who like themselves, claim to enjoy special facilities for communicating "mediumistically" with departed spirits, be persuaded to summon up for a few hours' conference the ghost of some permanent way superintendent who "passed away" say forty years ago, the interview would be at least interesting and might possibly lead us to form a more flattering estimate of the energy and ingenuity evinced by the said superintendent's successors than that we now hold. From the standpoint of 1835 the improvements embodied in the permanent way of 1875 might perhaps be noticeable; but most certainly ourselves glancing backward the differences traceable are insignificant. We have doubtless increased the strength and stability of our roads, but this desirable end has been attained by the expenditure of raw material and not of brains. The *Brutum fulmen* of our heavier engines has been opposed by the brute resistance of a bigger bar of iron, but both in general principle and in minor detail our design has continued unmodified. In making this assertion we have not forgotten the "fish joint," and we think if any illustration were needed of the thankfulness for small mercies shown by engineers in all matters concerning permanent way, it would be afforded by the fuss which has been made about this very obvious contrivance for joining a couple of bars together. Even now it is hardly possible for any question relating to permanent way to be discussed without some hot contention rising as to the claims of different men to be enrolled on the scroll of fame as the "inventor" of the fish joint. Poor Bridges Adams maintained to the last that it was a legitimate child of his own, and even his detractors conceded that he had christened it. We wonder what Tredgold would have said to a claim of this sort. We know what he wrote some few years before railways were talked of: "The simplest and perhaps the best method" (of joining beams) "is to abut the ends together, and to place a piece on each side; these when firmly bolted together form a strong and simple connection, and such a method is what ship carpenters call *fishing* a beam." The ghost of the man of '35 would probably be well up in his Tredgold, and he would consequently be more likely to congratulate us upon being able to afford the luxury which was denied him of fishing our rails, than compliment us upon the brilliancy of the conception.

We should be similarly foiled in every attempt to establish a claim for any other improvement in design effected during the last 40 years. The substitution of steel for iron is merely a question of £. s. d., outside of the railway engineer's department and consequently outside our argument. But it may be said that improvements have not been introduced nor even called for, because, by a happy inspiration, the pioneers of railway enterprise hit upon the right thing at first. This position cannot be defended, for it is notorious that from the earliest times there has been but one sustained growl about permanent way and its imperfections; so much so, indeed, that every bantling engineer in his turn enjoys his little joke about our iron roads being so termed, because there is nothing "permanent" about them. If any one doubts this, and does not fear too rude an awakening from his Fool's Paradise in which he dwells, let him take a walk any hot day along some line in the north of London, where the formation is of clay and the bottom ballast of burnt clay. Let him note how many of the wooden keys, whose assumed function it is to keep the rail wedged fast in the chair, are quietly reposing upon the ballast, and test how many of the remaining keys will be persuaded to leave their home in the chair by a gentle reminder with the forefinger. He will see a fine straight bar of steel, apparently supported at 3 ft. intervals upon chairs and sleepers. Let him investigate this point more closely and he will find that under perhaps one-half of the presumed supports he can readily pass his hand—

that the sleepers are, in fact, simply suspended from the rail. He will find chairs sledge-hammered by passing trains an inch or more into the soft wood, spikes partially withdrawn, treenails sheared off, and chairs fractured, and if in an entire mile of line he meets with a single sleeper which does not respond to a contemptuous kick by a visible and audible shudder through its entire system, he may safely infer that its immunity is due to recent attention from Dr. Platelayer and not to inherent soundness of constitution.

If the visit be paid to a line where a single-headed rail with a base flange resting immediately upon the sleeper is in use, the result will be little more reassuring. He will find the flange buried in the soft sleeper, and the heads of the fang bolts standing well up and innocent of all contact with the rail. If he attempt to screw down the fastenings, he will not improbably strip the thread or wrench the bolt asunder either in the fang nut or at its neck, which has been more or less cut away by constant attrition and pressure from the rail flange.

It cannot reasonably be contended, therefore, that permanent way needs no improving; hence we are driven again to ask ourselves what have the engineers of the last forty years contributed towards the desired end?

Forty years ago, three types of rails were in use—the *tee*, or single-headed rail, with little or no bottom flange; the *double-headed*, or reversible rail; and the *flanged*, or single-headed rail, with a base sufficiently wide to rest immediately upon the sleepers without the intervention of the chairs required with the two other type sections of rail. The *tee* rail was the earliest in the field, and singular to say, it is the form which is just now being reverted to almost universally by our engineers in relaying their lines with steel rails.

The *double-headed* rail was first used by Locke on the Grand Junction Railway in 1835, and in this country it has since reigned supreme; but is now, as we have already said, being deposed in favor of its prototype the *tee* rail.

The *flanged* rail has been popular with but few English engineers, but it is the form of rail which ever has been and still is the most generally preferred throughout the world at large.

The main features of the rails in use forty years ago being so far identical with our present practice, let us compare them a little more in detail to see what points of difference, if any, can be established.

In 1835 the standard section of *tee* rail weighed 50 lbs. per yard, of which about 22 lbs. would be found in the head proper The depth was 4½ in., the width of head 2¼ in., and of bottom flange, 1¼ in. The corresponding section at the present day may be given as a 78 lbs. steel, with about 44 lbs. in the head, and with a depth of 5½ in., a width of 2⅝ in. at the head, and of 2 in. at the bottom. The breaking weight applied at the centre of 3 feet bearings would be about 16 tons for the earlier, and 60 tons for the present rail. There is obviously no essential difference in the design of the two rails—it is merely a question of scale—we must, therefore, look to the chairs and fastenings if we are to show progress.

Previous to 1835, the rail was fastened in the chairs by iron pins, small iron wedges, or screw bolts, all rudely made and misfitting; but during that year a trial was made by Locke on the Liverpool and Manchester Railway of wooden keys, which, proving a success, were adopted by himself and engineers generally, to the exclusion of all other modes of fastening the rail in the chair.

It is hardly necessary to observe that the key of 1835 is the key of 1875, and that no progress can yet be reported. Our sole chance now is in the direction of the chairs themselves, and their fastening to the sleepers, but here again the avenue is blocked—Mr Cubitt's carriage "stops the way." In 1840 an exhaustive series of experiments was carried out by Messrs. Ransome and May, at Mr. Cubitt's request, to enable him to decide upon the form of chair and fastening which it would be desirable to adopt for the South Eastern Railway. Chairs of many different patterns were prepared and broken by wedging, until the best distribution of a given weight of metal was thus empirically determined. The chairs were cast on a metal core that they might all alike fit the rails, and the holes were placed on alternate sides of the centre line of the sleeper, so that the fastenings should not, by occurring in the same longitudinal fibre of wood, facilitate the splitting of the timber. The iron spikes ordinarily used at that time for securing the chair to the sleepers were strongly objected to by Mr. Cubitt, and with good reason, for he stated that he had known an instance where, in a length of 20 miles, 180 tons of chairs had been fractured in the process of driving the iron spikes. Various alterations were tested, but the final result of Messrs. Ransome and May's experiments was the adoption of compressed oak-tree nails to secure the chair to the sleeper, and compressed oak keys to fix the rail in the chair.

In the chair and fastenings, therefore, as in the rail itself, no improvement or beneficial modification of the design can be justly credited to the present generation of engineers. We have, it is true, doubled the bearing area of our chairs on the sleepers, but we have also doubled the weight of the chairs. We may ring the changes upon the fastenings, and at times use two treenails and one spike, and at other times two spikes and one treenail, but still we have the same old ingredients, and whatever objections originally applied to the *tee* rail and its adjuncts in 1835 apply with full force to the most favored type of permanent way of 1875. The same conclusion obviously applies to the *double-headed* rail and its fastenings, so it only remains now to see if our Continental brethren have been more faithful stewards than ourselves, and have improved in any essential respect upon the original type of *flanged-rail* permanent way—the legacy left them by the first generation of railway engineers.

The simplicity and cheapness of this form of permanent way, arising from the substitution of simple dog spikes for the complicated arrangement of chairs and fastenings, necessary with other sections of rails, at once recommended it to the attention of railway men. In Germany the flanged rail was in general use as early as 1835; but sixteen years later the whole question was reopened, and an elaborate series of experiments was instituted at the instance of the Prussian government to determine the best form of permanent way for the States railways. Chair rails, bridged rails, and flanged rails were impartially tested, and the final result of their experiments induced the Prussian government to adopt the *flanged rail* exclusively for all State railways. The most common type of permanent way in Germany is a rail about 5 in. high by 4 in. wide, spiked to the sleepers by two or three dog spikes, so neither in the general proportions of the rail nor in the mode of fastening is there to be traced any essential advance upon the earliest example of this type of road. That there is plenty of scope for improvement no one can doubt who reads Baron von Weber's exhaustive report upon the subject. The compression of the sleepers under the passage of a tank engine was found by him to be occasionally as much as $\frac{1}{4}$ in. with new timber, and no less than $\frac{3}{4}$ in. with old sleepers, and the result of this compression is the gradual destruction of the cellular structure of the wood, and a consequent cutting of the rail into the sleeper. Other experiments of Baron von Weber led him to the conclusion that the resistance of the soft wood and of the spikes was not sufficient to prevent a tilting of the rail and a widening of the gauge at times to a dangerous extent.

To obviate this cutting and tilting we must adopt one of two alternatives. We must either put plates under the rail, and so convert it, in one sense, into a chair rail, or we must extend the base of the rail itself until the requisite bearing area is attained. The latter course was adopted by Mr. Fowler in the instance of the Metropolitan Railway, where the rail is $6\frac{3}{8}$ in. wide, and but $4\frac{1}{2}$ in. high. The height and leverage for tilting forces is, therefore, but 70 per cent. of the width; on the Cologne-Minden railway the ratio is no less than 136 per cent.; but this is probably the least stable rail in use. The Northern Railway Company of France have accepted as their standard type of steel rail a flanged rail, weighing about 61 lbs. per yard, and measuring $4\frac{7}{8}$ in. high by $3\frac{13}{16}$ in. wide. The width of flange is not so great as in the iron rail previously used, the respective ratios of height to width being as 1.288 : 1, and 1.19 : 1. This narrowing of the base is an essentially retrograde step, and it is a direct traverse of the experience on German lines already cited, and also on the most important line in France, the Paris, Lyons, and Mediterranean, where the width of flange has been *increased* from $3\frac{15}{16}$ in. to $5\frac{1}{8}$ in. It is contended, however, by the Northern Railway officials that the experience of the two or three years during which this rail has been in use conclusively proves that the pressure on the sleeper is still well within the limits of its endurance.

The fastenings of the *flanged rail* have been little less a source of trouble to platelayers than those of chair rails. Dog spikes are drawn or canted; wood screws cease to grip when the wood is old, and fang bolts are stripped of the thread or wrenched asunder in the fangs, and with either system the work of replacing a rail is more or less tedious. Again, when the rails are notched or punched for dogs or bolts, the power to resist impact is seriously impaired, and frequent fractures result. It is generally considered that some provision must be made against longitudinal movement of the rails; but even upon this small matter engineers are not in accord. The administration of twelve German railways reported on this question a short time ago, and, while one company cited special instances where a dangerous longitudinal shifting of unnotched rails had occurred, the officers of three other companies were of the opinion that notching was not necessary if properly arranged joints were in use. On the Northern Railway of France the fish joint is placed over a sleeper, and a short spike is driven into the sleeper through a hole formed by the juxtaposition of an oblong notch in the flange of each rail end. The fastening of the rail in this instance consists of wood screws just touching the sharp edge of the unnotched flange—an arrangement eminently adapted to facilitate the shearing or cutting of the screw.

Still, with all its imperfections, the *flanged rail* maintains its original position of first favorite everywhere but in this country. In Russia, after a long discussion, it has been decided to adopt as the type section a steel rail 4¼ in. high by 3¾ in. wide at the bottom flange, and weighing 54 lbs. per yard. This differs but little from the rail used 40 years ago on the Southampton Railway, the weight of the said rail being 60 lbs., and its dimensions 4 in. by 3½ in. The test prescribed for the Russian rail is a weight of 16½ tons at the centre of 3 ft., bearings with a deflection not exceeding .15 in.; that of the forty-year old rail was a weight of 10 tons, with the same span and deflection. The steel rail has a thinner web, proportionately more metal in the head, and a squarer shoulder for the fish; but these are mere refinements of manufacture not attainable forty years ago, and in all essential respects the two systems of permanent way are identical. We may say, therefore, of the *flanged rail* as of the *tee* and *double-headed* type, that whatever defects existed in 1835 will be found in full force in the best examples of 1875; and the answer to our question, What have the engineers of the last forty years contributed to the improvement of permanent way? is but too obvious. Whole "volumes in folio" have been compiled on the subject, and if "specifications" are any evidence of good intentions, enough will be found at the Patent Office to pave the entire area of the engineer's department in the retreat on the wrong side of the Styx. Still, if the spirit of the man of 1835 appeared in answer to our summons, we should have to direct him to the Patent Office, and not to the railways of the world, if we intend him to be informed of the labors of his successors in the matter of permanent way.

Dr. Lawson has recently published some curious observations regarding the time of the day when the greatest and least number of deaths occur. He finds, from the study of the statistics of several hospitals, asylums, and other institutions that deaths from chronic diseases are most numerous between the hours of eight and ten in the morning, and fewest between like hours in the evening. Acute deaths from continued fevers and pneumonia take place in the greatest ratio in the early morning, when the powers of life are at their lowest, or in the afternoon, when acute disease is most active. The occurrence of these definite daily variations in the hourly death rate is shown, in the case of chronic diseases, to be dependent on recurring variations in the energies of organic life; and in the case of acute diseases, the cause is ascribed either to the existence of a well-marked daily extreme of bodily depression, or a daily maximum of intensity of acute disease.

—*The Engineer.*

BOILER EXPLOSIONS.

Translated from Dingler's "Polyt. Journal."

The assigned causes of boiler explosions, other than bad material, bad construction and defective work, are—

1. Excessive steam pressure.
2. Electricity.
3. Explosive gas.
4. Leidenkroft's phenomenon (spheroidal condition).
5. Retardation of boiling.
6. Sudden discharge.
7. Shocks of the boiler-walls.
8. Red-hot boiler surface.

1. Excessive pressure very rarely is the direct cause of explosion; *i. e.*, of so sudden a destruction of the boiler that it is torn into fragments which are hurled to a distance. This powerful energy, according to Grashof, can be due only to the sudden conversion of a great quantity of heat into work. It is known that boilers, in certain circumstances, have borne a strong steam tension, though examination has shown that holes could be struck into them with a small hammer. Experiments by Andraud show that iron boilers of 100 litres capacity and 2 millimetres strength burst under a pressure of 75 atmospheres, but never explode.

The experiments of Stevens and those of a United States commission show that excessive pressure in a boiler which has weak spots, makes a rent (in case of a brittle iron a hole caused by the flying out of a fragment), while in all probability, it would cause an explosion only in case of absolute homogeneity of wall. But the bursting (tearing) may be the occasion of an explosion.

2. Andraud supposes that electricity is generated during the conversion of water into steam, which may lead to explosions; and he recommends the use of conductors.

Jobard thinks that under certain conditions the numerous tubes act as Leyden jars to collect the electricity.

It is obvious that the fact is here lost sight of that free electricity collects only on the surface of the boiler which is never insulated; besides, it is not obvious that electricity can explode.

Lardner attributes the explosion of a locomotive to a stroke of lightning which so heated the boiler that explosion was caused by the sudden expansion: a very questionable hypothesis. Wilder's hypothesis is no better: that the explosion is due to the sudden development of free caloric.

3. Perkins thinks that the cause is the sudden decomposition of water; Mackinnon, that hydrogen is generated by the heated surfaces, and that the admission of air by the valves forms an explosive mixture.

Du Mesnil thinks that hydrogen is generated by the vapor from oil, and the decomposition of the water, forming an explosive mixture with the oxygen of the feed-water, which is set on fire by an electric spark. Schiele is of the same opinion.

Jobard maintains that the water is decomposed by the red-hot boiler surface, or that the organic products in the feed-water are converted into a kind of steam; and if the feed-pump does not dip under water so that air is pumped (?) into the boiler the mixture is exploded by an electric spark, or by the red-hot organic products.

Hipp attributes explosions solely to a mixture of gases, but is contradicted by Grashof.

The experiments of the Franklin Institute, of Philadelphia, have shown that water in a red-hot boiler with clean surface, but not polished, is not decomposed. And Schafhaütl has shown that 1 vol. of explosive gas mixed with 0.7 of steam will not explode. Parkes says that during the blowing out of a hot boiler an inflammable gas is generated which bursts into a flame at the opening of the man-hole, but it is plain that little hydrogen can form during the working of an engine. Were greater quantities of inflammable material converted into gases, these could be so thinned by the steam that on entrance of air, even in case of red-hot surfaces, an explosion is not probable.

Woolfe and Taylor suppose that explosions originate in the boiler flues. If the burning fuel is covered with fine coal or ashes, and the door is shut, gases are formed, which explode when the door is again opened. Hand and Wabner are of like opinion.

That inflammable gases may gather in the flues is obvious, but it is improbable that the explosion should be violent enough to burst the boiler. But this may under conditions (as 1, 5, and 7) be the direct occasion of an explosion. The register should first be opened, then the furnace door, in order to get rid of the gas.

4 Boutigny assigns as the common cause of explosions the spheroidal condition of the water in the boiler (Leidenfrost's phenomenon). A white-hot ball of metal sinks in boiling water and becomes enveloped in a coat of steam. When the ball cools there ensues a sudden development of steam, and a consequent explosion. Barret supposes that dirty water aggregates into spherical forms which act in a similar manner.

5. Dufour has shown that water drops of 10 millimetres diameter, floating in oil, can be heated to 175° without generating steam, and that by diminution of pressure a great retardation of boiling point may be caused. Donny heated water free from air to 135° under ordinary pressure. Similar results have been obtained by Schmidt, Krebs, Tyndall, and Gräger.

Dufour concludes that while the engine is not in operation so that by the cooling of the steam spaces the pressure becomes less, the water attains a higher temperature. A sudden shock or the opening of a valve induces boiling and copious generation of steam.

Heinemann, Kirchweger, Rühlmann, and Reiche deny the possibility of a retardation of boiling; while Werner, Froning, Ludewig, Blum, Scheffer, Jacobi, Fuhst, Langen, Stuhlen, and Witmann take the opposite view.

Burnat and Mayer have observed this retardation, and its possibility must be granted, under the condition of water free from atmosphere or charged with oil.

It is doubtful whether a good boiler can be destroyed in this way; but when causes 1, 6, and 7 concur, an explosion may result. Donny proposes to prevent retardation by blowing a stream of air into the boiler; Cohn, by the use of electricity.

Williams asserts that water in the condition of strict fluidity always has the temperature of melting ice; the apparent heat being due to that of the steam distributed throughout the fluid. He thinks too great a quantity of water in the boiler may lead to an explosion upon the opening of the valve.

6. Parkes says that of 23 cases of explosion 19 occurred at the moment of starting the engine; others when the safety-valve was opened.

The experiments of the commission of the Franklin Institute show that, when an opening is made in a boiler, from which the steam can escape, a sudden foaming takes place in the vicinity of the opening, soon followed by a foaming throughout the boiler; the violence being in proportion to the size of the opening. A small boiler was entirely filled with foam upon the opening of the safety-valve, so that the water was greatly agitated. Compare the experiments of the Breslau Society of Engineers (Dingler's P. J., 1865, 1867).

The explosion of the steamer Citis at Bordeaux was explained by the fact that at the opening of the valve the gradual generation of steam changed to a violent boiling and hurling about of the water, so closing the valve (which allowed the passage of steam, but not of water); and the steam pressure became too great for the resistance of the boiler.

If the tension in a boiler is suddenly diminished by the cooling of the water, the opening of a valve, or bursting of a tube, there results a sudden generation of steam, followed, under certain conditions, by the hurling of the water against the walls with great violence. This theory, first advanced by Colburn, is adopted by Berguis, Hoffmann, Werner, and Kurz. Grashof has shown that a boiler may be sprung by the sudden production of steam consequent upon superheating the water. A tension uniformly increasing causes, as before stated, a gradually widening rupture in the weakest part of the boiler; while sudden increase of tension may cause simultaneous burstings in several parts. The water is suddenly subjected to atmospheric pressure only; a great quantity of steam is immediately generated, having the temperature of the heated water, and the heat is converted into dynamic energy.

Kayser thinks that a shock is caused by the sudden formation and projection of masses of steam. Geisberg, Jacobi, Heinemann, Welkner, and others are of the same opinion. Ludewig shows that the theories of Dufour and Kayser supplement each other.

7. Schafhaütl filled glass tubes 5 centimetres long one-fourth full of water, and put them into melted zinc (412°). They withstood the enormous pressure of 400 atmospheres, but exploded with great violence when struck by a swinging iron rod. He is of opinion that great pressure alone does not cause explosions; but they may occur when this is attended by vibrations of the boiler walls; as has actually transpired in a case when a boiler was struck with a hammer, and in another when one was struck by a small stone. That such is the cause of explosion is doubtful. When combined with causes 1 and 5 it may ensue.

8. The heat that occasions explosions may be not only that of the water, but also that of the boiler walls. This may be due to low water, boiler incrustations, and slime.

The Franklin Institute commission found that when water was injected upon the surface of a small red-hot boiler, great tension was produced. But Taffin found only that the boiler shell was warped under like circumstances.

Other experiments have shown that the result of injecting cold water upon the superheated surfaces was that the iron contracted so much that the rivets were loosened. The experiments of Fletcher and of the Pennsylvania R. R. Society have shown that the explosion of a superheated boiler, by the sudden admission of feed-water, is impossible.

The hypothesis that superheated steam may become saturated and of such great tension as to induce explosion, as a consequence of heated boiler surface, is disproved by the experiments of the Franklin Institute.

Perkins is of opinion that when the water is low the steam may become so superheated as to heat the boiler surface red hot even under water. Upon the opening of the safety-valve the water takes up the heat and is suddenly converted into steam, inducing an explosion.

It has long been known that incrusted boiler surfaces may be made red hot. If the crust suddenly breaks up, a copious generation of steam ensues that may be the cause of an explosion. Cousté maintains that explosions would be prevented by preventing this incrustation. Williams and Peschka conclude from the results of experiments that solid crystalline incrustations are less dangerous than those of a porous nature.

Regard should be had to the fact that iron when red hot has a diminished power of resistance; being reduced, according to the experiments of the Franklin Institute, to one-sixth the ordinary amount; the maximum, however, occurring at a temperature higher than that of ordinary steam. According to Wortheim, some metals, especially iron, attain a maximum of elasticity at a mean temperature. Another authority states that iron at 300° is 16 per cent. stronger than when cold. Kupfer gives as the decrease of elasticity for each degree in the case of

Iron	0.00055
Copper	0.00082
Brass	0.00039

The recent experiments of Kohlrausch and Loomis are noteworthy. Denoting the modulus of elasticity at 0° by E°, the modulus at the temperature t for

Iron is ... $E = E^0 (1 - 0.000447t - 0.00000012t^2)$
Copper is $E = E^0 (1 - 0.000520t - 0.00000028t^2)$
Brass is .. $E = E^0 (1 - 0.000428t - 0.00000136t^2)$

Referring the definition of the modulus of elasticity not to the linear unit, but to the sectional, the factors of t

Are for Iron	0.000483
" " Copper	0.000572
" " Brass	0.000485

Hence from 0° to 100° the elasticity diminishes

For Iron	4.6	or 5	per cent.
" Copper	5.5	" 6	" "
" Brass	5.6	" 6.2	" "

the second column corresponding to the second definition. Hence it is apparent that the hypothesis that a maximum is attained at a mean temperature is incorrect.

Overheating the boiler permanently diminishes the tenacity of the metal by one-third. Riveting also diminishes it by one-third; so that boiler iron will not resist by more than one-fifth its normal strength. Schafhaütl found that a boiler capable of resisting, under ordinary circumstances, a tension of 20 atm., after it had been overheated at low water, exploded under 12 atm. The iron was found to be charged with sulphur. The risk of such a result increases with the temperature.

Ward observed the temperatures in two boilers. Under the water-line the thermometer stood 131.6° and 135.5°; in the steam-space between 201° and 260°. The surface of the water oscillated through a space of 15 centimetres, so that at some points on the boiler surface there was a sudden rise of 128°.

A boiler which was tested for 9 atm. pressure with cold water exploded soon after at 3 atm. The test with cold water (hydraulic press) is regarded by many as utterly worthless.

Finally, we have sufficient reason to consider incrustation and sediment as the worst enemies of the boiler in respect to both economy and safety.

REVIEW OF THE MOTORS OF THE VIENNA EXHIBITION.

BY V. DWELSHAUVERS-DERY.

From the "Review of Mining."

In the year 1862, in London, Allen exhibited in the American section a steam-engine constructed on principles which were new to the practice of that time. There was also an example of the Corliss engine, but in such a state of infancy that it was passed by almost without notice. At the Universal Exhibition in Paris, in 1867, the Corliss engine, represented by two different systems of valve motion (Ingliss and Spencer in the English section, and Corliss in the American), took all the honors and achieved all the success, while the Allen engine, the principle of which was the same, remained unnoticed. Its success is so great that, while the engine of the Bros. Sulzer, with valves, of no less admirable construction than design, is left in obscurity and finds no imitators, the Corliss engines are quite in vogue, as the Universal Exhibition of Vienna sufficiently proves. Here also we encounter still newer systems, such as those of Berchtold (of the firm of Scheller and Berchtold, Thalweil, near Zurich), highly finished, and of Dautzenberg (a single specimen), which are distinguished from the Corliss and Allen engines by details of construction, but the inventors of which have endeavored to attain the same object. This same object is now actively sought after by manufacturers; it must, therefore be rational. Let us endeavor to expound it.

End to be attained.—To admit at each stroke a small quantity of steam, at a pressure equal to that in the boiler; to draw it out by a long expansion, variable by the governor, according to the load; this is the real object to be sought after, one which promises economy and regularity. Condensation and steam jacketing are some of the known means which, added, to others, tend to the accomplishment of the desired end, but without changing the particular system employed.

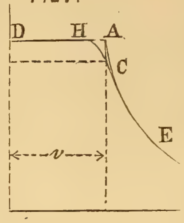
Exaggerated size of the Woolf engines.—If but little steam be admitted, and if the expansion be considerable for a given power, the steam cylinder and the whole engine assume very large proportions. One is deceived, if one attempts to reduce them by the use of the two cylinders of Woolf. In fact, if v represents the volume of steam admitted at each stroke, and 12 the degree of expansion, it follows that at the end of each stroke the volume occupied by the steam will be 12 v; now at this point the whole of the steam is contained in the large cylinder; the capacity, therefore, of the large cylinder is $V = 12\ v$. Under the same conditions, the cylinder of a single-cylinder engine should have a capacity equal to 12 times the volume of the steam admitted, or, in other words, it also is represented by $V = 12\ v$. It follows, then, that for the same admission of steam the large cylinder of the Woolf engine must have the same capacity as the single cylinder of another. The small cylinder of the Woolf engine is, therefore, a costly addition, which might have the effect perhaps of assisting in the work of the governor, or in the distribution of the heating surface of the steam jacket, but which certainly in no way helps to diminish the size of the engine, the cost of its manufacture, or the expense of a sinking fund.

Speed of the Piston and high Pressures.—If, then, we wish to reduce the size of the engine, adopting at the same time a long expansion, one only method presents itself, which is to increase the speed of the piston. With low pressures and large admissions of steam, Watt had a piston speed of a little more than a metre per second. Stephenson introduced high pressures; large expansions (of three, four, and five times the volume admitted) came next into vogue, while the same piston speed was invariably maintained. The aim is now to increase the degree of expansion, preserving at the same time high pressures and condensation, whence it follows that a high piston speed becomes necessary. Allen adopted a speed of 2 metres per second, and it has since been raised to even 3 metres. This is an exaggeration which, except in the case of locomotives, cannot often be followed. The prevalent speed seems to be one and a half to two and a half metres, according to the power.

Consequences of high Piston Speed.—It is easy to perceive the consequences which follow the adoption of high speeds of piston. The time which the steam will have to pass into the cylinder will be so much shorter. If it be desired to maintain the boiler pressure at the point of admission, it will be necessary that the steam port shall be opened rapidly and to a great extent, and that it be also closed sharply; whence it follows that the port should be long and narrow, in order that the travel of the slide-valve should be very short; whence also arises the seeking after a cinematic arrangement calculated to increase the speed of the valve during the opening of the port, and, lastly, the use of springs to make it close smartly.

Sharp closing of the ports.—Let us be permitted a few observations concerning this sharp closing of the ports, which several mechanical engineers, following in the wake of Corliss, take so much pains to achieve. The use of springs in the admission and emission of steam is so contrary to the opinions of so many engineers that it is better to avoid them; and, after all, the sharp closing of the port is, to say the least, of doubtful utility. In fact, let D A E (fig. 1) represent the diagram of pressures in the case of a smart closing of the port, and D H C that which a slower closing would give; the difference in the areas of the two diagrams, very nearly equal to the area of a small curvilinear triangle, H A C, constitutes the loss of power in the second case. Power is gained then undoubtedly in closing the port sharply; but, on the other hand, more steam is expended, for the volume of steam at the instant of closing is the same in both cases, but the pressure A B, and consequently the weight of steam expended, are greater when the port is closed sharply; A B is greater than C B.

Fig. 1



There is only one advantage in a smart closing of the port, but it is too slight to cause so much attention, and especially to complicate the action of the slide-valve by such an elaborate system of springs. It is, that as the diagram with slow closing of the port presents a smaller area than the other, a slightly larger cylinder is required in order to obtain the same power at each stroke. The advantage is, however, so slight that it is hardly worth while to take this circumstance into account.

Dead Space.—A more interesting subject is presented by the dead space, which may be considered under two heads, important to be distinguished from each other. It would never do to allow the piston to come in contact with the cylinder covers; it is also necessary to preserve the desired clearance, so that no accident may result from a displacement of any of the parts, either by wear at the joints or any portions of the piston becoming unscrewed. The very boldest constructors leave five millimetres (0.1965 in.) of clearance for a stroke of one metre. This is the first head, and the loss, which we estimate at $\frac{0.005}{1.000}$, say $\frac{1}{200}$, is unavoidable. That under the second head is the content of the steam passage from the end of the cylinder to the valve face, a part which is essentially variable, and capable of being much reduced. We estimate it as follows: For admission and emission by a single slide, the smallest possible, the steam passage between the end of the cylinder and the valve face situated in the middle of the cylinder, may have a length approximately equal to half the stroke of the piston, provided, however, that the valve face be not too far from the centre line of the cylinder. If the area of the section of the passage is one-twentieth that of the piston, the content of the passage will be $\frac{1}{20} \times \frac{1}{2} = \frac{1}{40} = 0.025$ of the volume (V) which the piston produces in a stroke. In this case, the total volume of the dead space is, therefore, $0.025\ V + 0.005\ V = 0.03\ V$, say 3 per cent. of the capacity of the cylinder.

Influence of speed on the size of the Dead Space.—If, on account of the great speed of piston, a larger section be given to the steam passage; if, for instance, this section be doubled as in the Corliss engine, it becomes necessary to diminish the length of the passage. This, in fact, is what is done by placing the steam ports at the ends of the cylinder. The length of the passage is thus reduced more than half. But considerations, which we shall mention further on, induce the constructor to keep the valves of emission separate from those of admission; whence arises a second steam passage, the content of which must be added to that of the former to arrive at the second portion of dead space. In a word, this arrangement of the steam ports has the effect of reducing the dead space to about two per cent., provided that the error be not committed of considerably augmenting the dead space by a faulty arrangement of exhaust valves, as in the Ingliss and Spencer engine. Such a separation of the steam and exhaust valves necessarily causes an increase in the cost of the engine. It is important, therefore, to know if the effect of the dead space is sufficiently injurious to warrant such an increase in the sinking fund; and this is what we will now discuss.

We will suppose that during this expansion, the pressure of the steam follows Mariotte's law, however the hypothesis may differ from reality; but the error we shall thus commit can be of no consequence since a comparison only is in question. We will also suppose that the valve has neither lead nor lap, and that the back pressure is equal to the pressure in the condenser or that of the atmosphere, from the commencement to the end of the back-stroke; or, at any rate, that there shall be no premature closing of the exhaust port, and consequent compression in the dead space; we will inform the reader when this last condition is realized. To make our deductions more easily understood, we will take a particular case, one that frequently occurs in practice. The pressure of steam at admission (P) will invariably remain at five atmospheres absolutely; if it be a condensing engine, the back pressure will be one-tenth of the atmosphere, say $\frac{P}{50}$; if not, it will be one atmosphere, say $\frac{P}{5}$. We will remove the limits of the expansion as far as is the case in practice or as economy requires. In the case of condensing engines, we will suppose that the admission is continued up to the tenth part of the stroke, and, in the case of non-condensing engines, up to the fiftieth part, in order that the final pressure be not less than that of the atmosphere.

Variation of the influence of the Dead Space with the Expansion.—Let us remark, in the first place, that the influence of the dead space increases in inverse ratio to the admission. In fact, let us suppose that $0.02\ V =$ the minimum of dead space which it is possible to attain by the most favorable arrangement of the steam ports consistent with the exigencies of construction. If the engine is working at full pressure, the volume of steam actually expended at each stroke, less the quantity of steam remaining in the dead space at the pressure of the condenser or of the atmosphere, is equal to 1.02 V instead of V; say an excess of 2 per cent. If the expansion begins at the middle of the stroke, the volume of steam expanded is equal to 0.52 V, instead of 0.5 V; say an excess of 4 per cent. If the steam is cut off at a tenth of the stroke, the volume of steam expanded is equal to 0.12 V instead of 0.1

V; say an excess of 20 per cent. The dead space seems, therefore, to be prejudicial in direct proportion as the expansion is greater; consequently the adoption of a high degree of expansion necessitates, from an economic point of view, the reduction of the effect of the dead space. But let us calculate these effects.

First case.—Condensing engine, theoretically perfect, without any dead space, cut-off at a tenth of the stroke. The work given out by a stroke of the piston is,

$$T = \frac{PV}{10}(1 + \log. 10 - 0.2) = 0.31026\ PV.$$

The volume of steam expended is

$$W = \frac{V}{10}.$$

Consequently the work done by the expenditure of a cubic metre of steam is $K = 3.1026$ P.

Second case.—Same conditions, but the dead space is $0.005\ V = 0.05\ \frac{V}{10}$. At the commencement of the stroke, as the dead space is filled with steam at the pressure $\frac{P}{50}$, there will be required, in order to fill it with steam at the pressure P, a volume equal to $\frac{49}{50}$ of that of the dead space; so that the expenditure of steam in excess is $\frac{49}{50} \times 0.005$ V, or say 0.0049 V.

Let us now try to find what should be the degree of expansion n, in order that, taking into account the dead space, the work done by a stroke of the piston should still be $T = 0.31026$ PV.

To this end we shall have to solve the following equation, in which n is the unknown quantity:

$$\frac{PV}{n} + P\left(\frac{V}{n} + 0.005\ V\right)$$

$$\log. \frac{V + 0.005\ V}{\frac{V}{n} + 0.005\ V} - \frac{PV}{5} = 0.31026\ PV.$$

This becomes:

$$0.33026\,n - \frac{200+n}{200}\log. \frac{201\,n}{200+n} - 1 = 0;$$

it will be found within a hundredth part, that $n = 10.35$.

The volume produced by the piston during the admission is then

$$\frac{V}{10.35}.$$

It follows that the volume of steam admitted is

$$W_1 = \frac{V}{10.35} + 0.0049\ V = 0.10152\ V.$$

The force produced by a cubic metre of steam is then:

$$K_1 = \frac{0.31026\ P}{0.10152} = 3.0561465\ P.$$

Whence $K - K_1 = 0.0465$ P.

The loss per cent. arising from the dead space is, therefore,

$$\frac{4.65}{3.1026}, \text{ or about } 1.5.$$

This is approximately the loss in such engines as Bède and Farcot's, where the steam port is actually in the cylinder cover. We shall see by the following how far this new complication is warranted.

Third case—Supposing the dead space to be 0.03 V. In order that the force produced by a stroke of the piston should be equal to T, the degree of expansion should have the value of n in the following equation:

$$\frac{PV}{n} + PV\left(\frac{1}{n} + 0.03\right)$$

$$\log. \frac{1.03}{\frac{1}{n} + 0.03} - 0.2\ PV = 0.31026\ PV;$$

whence $n = 12.21$, correct to a hundredth part.

The volume of steam expended is then

$$W_2 = \frac{V}{12.21} + \frac{49}{50} \times 0.03\ V = 0.1113\ V.$$

The force produced by a cubic metre of steam is therefore,

$$K_2 = \frac{0.31026\ P}{0.1113} = 2.7876\ P; \text{ whence } K - K_2 = 0.315\ P.$$

The loss is consequently 10.15 per cent.; whence it is evident that there is abundant reason to reduce, as much as possible, so considerable a loss. We will show how this can be accomplished without complicating the arrangement of valves.

In the cases of the imaginary engines, which we have just examined, the loss increases nearly in proportion to the content of the dead space. This also happens in the following cases.

Fourth case.—Non-condensing engine, steam cut off at one-fifth of stroke, theoretically perfect, without any dead space. The force produced by a stroke of the piston is:

$$T' = \frac{P\,V}{5}(1 + \log. 5 - 1) = 0.3218876\,PV.$$

The volume of steam admitted being

$$W' = \frac{V}{5},$$

the force produced by each cubic metre of steam expended is $K' = 1.609438$ P.

Fifth case.—Same conditions, except that the content of the dead space is 0.005 V. At the commencement of the stroke, as the dead space is filled with steam at the pressure $\frac{P}{5}$, there is required, in order to fill it with steam at the pressure P, a volume equal to $\frac{4}{5}$ of that of the dead space, so that the expenditure of steam in excess is $\frac{4}{5} \times 0.005$ 0.005 V $= 0.004$ V.

Let us further see what should be the degree of expansion n, in order that, taking the dead space into account, the force of one stroke of the piston should be $T' = 0.3218876$ P V. The degree of expansion will be the value of n in the equation:

$$\frac{PV}{n} + PV\left(\frac{1}{n} + 0.005\right)$$

$$\log. \frac{1.005\,n}{1 + 0.005\,n} - \frac{PV}{5} = 0.3218876\,PV,$$

$$\text{or } 0.5218876\,n - \frac{200 + n}{200}$$

$$\log. \frac{201\,n}{200 + n} - 1 = 0$$

It will be found that $n = 5.06$ within a hundredth part.

The volume of steam expended is then:

$$W_3 = \frac{V}{5.06} + 0.004\,V = 0.20163\,V.$$

The force per cubic metre of steam expended:

$$K_3 = \frac{0.3218876\,P}{0.20163} = 1.59642\,P.$$

Whence may be deduced: $K' - K_3 = 0.013$ P, or about 0.8 per cent. minimum loss, as will be seen.

Sixth case.—The same conditions; but the volume of the dead space is 0.03 V. Continually following the same course, the degree of expansion will be the value of n, which satisfies the equation:

$$\frac{1}{n} + \left(\frac{1}{n} + 0.03\right)$$

$$\log. \frac{1.03\,n}{1 + 0.03\,n} - 0.5218876 = 0.$$

It will be found that $n = 5.405$ within a hundredth part.

The volume of steam expended is:

$$W_4 = \frac{V}{5.405} + 0.03 \times \frac{4}{5}\,V = 0.209\,V.$$

The work per cubic metre:

$$K_4 = \frac{0.3218876\,P}{0.209} = 1.5401\,P.$$

Whence $K' - K_4 = 0.06934$ P, that is to say, about 4.3 per cent. In these engines, then, the loss has still increased nearly in proportion to the volume of the dead space.

Conclusion.—We must now draw our remarks to a close. It seems to us that we have conclusively shown that the influence of the dead space is by no means to be ignored, and that we reduce the loss arising therefrom in proportion as we reduce the space itself. The track, then, on which engine builders have entered is the right one. But still better can be done; *the loss in question can be reduced to zero by closing the exhaust port sufficiently soon for the steam, compressed and reduced to the volume of the dead space, to have, at this moment, a pressure equal to that of admission.*

Means of counteracting the prejudicial effect of the dead space.—These can easily be conceived. For, let us suppose that the dead space be filled at each stroke with steam which costs nothing, the volume of steam will remain invariable, and equal to v, for instance, and the force per cubic metre will also be constant. Now, if, as we have said, the exhaust steam, escaping into the dead space, be compressed, the force necessary to compress this steam is given out in the expansion at the next stroke without any other loss than increased friction of the engine, of which we take no account at present. But this process presents an actual disadvantage; the dimensions of the cylinder, to obtain the same power, must be increased. Let us see to what extent this must take place, in order to state the matter clearly, and to determine if, and on what occasion, it is more advantageous to compress the exhaust steam than to complicate the admission and exhaust valves.

The problem which is here presented is as follows: A volume v of steam, working at full pressure, with expansion, and with full back pressure in a cylinder without dead space, gives out per stroke a power T, the content of the cylinder being V. It is required to find what should be the capacity of a cylinder having a known dead space, in order that, while expending the same volume v of steam and compressing the steam resulting from back pressure until it is compressed to the same extent as the steam at admission, the power given out at one stroke should be equal to T.

We will proceed to solve this problem in the four cases which we have already noticed.

First case.—Pressure at admission, five atmospheres, back pressure, 0.1 *atmosphere; cut-off at one-tenth of the stroke in the cylinder theoretically perfect*; *content of dead space* 0.005 V; *say* 0.05 v. *The power* T=3.1026,Pv.

In the first place, let us see when the compression should begin. If we grant that the law of Mariotte is true for the cempression as well as the expansion, the former should commence when the piston, before reaching the end of the stroke, shall have to produce a volume equal to forty-nine times that of the dead space, so that the initial volume shall be fifty times that of the dead space. The compression, then, will commence when the piston has still to traverse the volume $49 \times 0.05\ v$. If $n\ v$ represents the volume sought to be produced by the piston at each stroke, the full back pressure will take place while the piston gives rise to the volume $n\ v—49 \times 0.05\ v = n\ (n — 2.45)$. As to the force of the compression, it will be $P \times 0.05\ v \log. 50$.

We shall have, then, in order to enable us to calculate n, the formula:

$$T = P\,v + P \times 1.05\ v. \log. \frac{n + 0.05}{1.05} - \frac{P}{50}\,v\,(n - 2.45) - P \times 0.05\ v \log. 50,$$

which leads to $1.05 \log. (20\ n \times 1) — 0.02\ n — 5.4459348 = 0$, or $\log. (20\ n \times 10 — 0.0082724\ n — 2.50635 = 0$, whence, $n = 10.91$ within a hundredth.

The volume which the piston should produce per stroke is, therefore, 10.91 v, instead of 10 v, that is to say 9 per cent. more. If the enlargement be made in the diameter, this will be scarcely appreciable. But in many cases it would be preferable to lengthen the stroke, because the dead space increases in direct proportion with the diameter, while it decreases as the stroke is lengthened, if the ports are placed at the ends of the cylinder.

Second case.—Same conditions, except that the volume of dead space is 0.03V, *that is to say,* 0.3 v *approximately.*

Compression will commence when the volume of steam on one side the piston is fifty times the volume of the dead space on the other, or 15 v. The piston will then have to traverse a volume $15\ v —0.3\ v = 14.7\ v$ before reaching the end of the stroke. We shall have the following equation to enable us to find the value of n:

$$P\,v + P\,v \times 1.3 \log. \frac{n + 0.3}{1.3} - \frac{P\,v}{50}\,(n—14.7)—Pv \times 0.3 \log. 50 = Pv \times 3.1026.$$

$$\text{Or, } \log. (n + 0.3) — \frac{n}{65} — 2.5563695 = 0,$$

whence we obtain, correct to one place of decimals, $n = 16.25$.

The volume which the piston should produce at each stroke is then 16.25 v. The back pressure will only, therefore, be equal to the pressure in the condenser, while the piston forms with the cylinder a volume equal to 1.55 v, that is to say, less than a tenth part of the stroke. These conditions differ widely from what is observed in ordinary practice; yet we think that they may be advantageous. However, a dead space of 0.3 v is quite the maximum that has been attained, or that can be attained, by increasing the size of the exhaust ports, so as to exhaust the cylinder in a tenth of the stroke, and by dividing the increase of content between the diameter and the stroke. If however, a certain loss be submitted to, there need not be so much compression; but this will always lead to some gain.

Third case.—Pressure of steam at admission, five atmospheres; back pressure, one atmosphere; cut-off at one fifth the stroke in the cylinder theoretically perfect; content of the dead space, 0.05 × 5 v, *that is,* 0.025 v. The force T = 1.609-438 P v.

The compression should commence when the volume, which remains for the piston to traverse, is four times that of the dead space, or 0.1 v. We shall have then, for the volume at full back pressure, $n\,v - 0.1\,v = (n - 0.1)\,v$, and the force of the compression will be P × 0.025 v log. 5.

We shall have, then, to enable us to calculate n, the equation:

$$T = P\,v + P \times 1.025\,v \log. \frac{n \times 0.025}{1.025} - \frac{P\,v}{5}(n - 0.1) - P \times 0.025\,v \log. 5.$$

The solution of this equation is very simple: let $c\,v$ be the volume of dead space, the equation to resolve will be:

$$P\,v \log. 5 = P\,v - P\,v\frac{n - 4\,c}{5} + P\,v\,(1 + c)\log. \frac{n + c}{1 + c} - P\,v\,c \log. 5.$$

This equation is solved in the easiest manner thus: $n - 4\,c = 5$, since, in the case of $n - 4\,c = 5$, we have:

$$P\,v\,(1 + c)\log. \frac{n + c}{5\,(1 + c)} = P\,v\,(1 + c)\log. 1 = 0,$$

$$\text{and } P\,v\left[1 - \frac{n - 4\,c}{5}\right] = 0.$$

This solution, which is, however, the only acceptable one, recurs to inform us that, independently of the portion of the stroke that takes place during compression, the volume at full back-pressure $v\,(n - 4\,c)$ is equal to 5 v, that is to say, invariable. In the present case, then, we shall have, $n = 5 + 4\,c = 5.1$, or an increase of 2 per cent.

Fourth case.—The same as the preceding except that the content of the dead space is 0.03 + 5 v = 0.15 v.

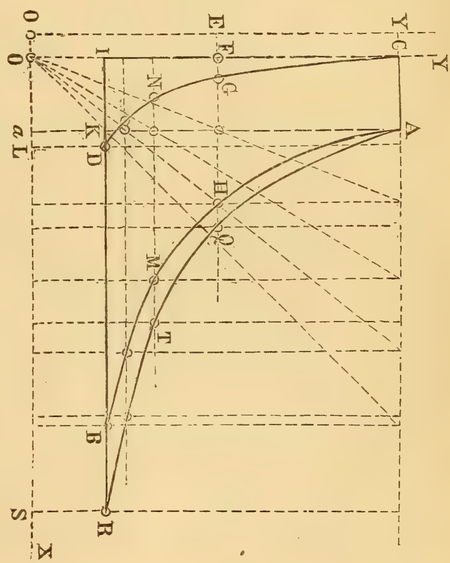
In accordance with the general formula which we have just pointed out, we shall find,

$$n = 5 + 4\,c = 5 + 0.6 = 5.6;$$

that is to say, the volume produced will be 12 per cent. greater with than without back pressure, a proportion which will be quite acceptable in practice.

Note.—The general solution which we

FIG. 2.



have just given is independent even of the law of Mariotte, and applicable to every curve, the equation of which is in the form of

$$P\,v^{m} = \text{constant.}$$

Let us demonstrate it, in the first place, by a diagram, for the case in which $m = 1$, the case of Mariotte's law. In fig. 2, let O Y and O X represent the two rectangular axes, one, O X, of the volumes, and the other, O Y, of the pressures; also A M B the hyperbola, having for equation

$$x\,y = \overline{CA} \times \overline{Aa} = v\,P,$$

which represents the pressures in the case where no dead space exists. Its surface,

a A B X, represents the force of a stroke of the piston, since this force is equal to: $O\,a\,C\,A + a\,A\,B\,X - I\,B\,X\,O = a\,A\,B\,X$, since $O\,a\,C\,A = I\,B\,X\,O$.

Let us now consider a dead space of O O′, and let us trace the curve of compression; it will be a hyperbola, having O′ Y′ and O′ X for asymptotes; its equation will be:

$$x'y = \overline{Y'A} \times \overline{A\,a} = c\,v\,P.$$

The curve will be C G N D, and the force of the back pressure will equal the area O C N D L.

Let us draw a series of horizontal lines, as E F G H, and, from the point H, where they meet the first hyperbola, let us produce them each from its portion corresponding to F G, so that

$$\overline{G\,Q} = F\,H = x; \text{ whence:}$$

$$\overline{E\,Q} = \overline{E\,G} + \overline{G\,Q} = x' + x = X\,y\,(x' + x)$$
$$= y\,X = v\,(1 + c)\,P = \text{constant.}$$

The curve A T R is, then still a hyperbola, having for asymptote O′Y′ + O′X; and it is easy to see that the area D C A T R D is equal to the area I C A B I, the infinitesimal areas corresponding to $\overline{d\,y} \times \overline{F\,G}$ having been simply transported so as to become $\overline{d\,y} \times \overline{H\,Q}$. This is the graphic method which has enabled us to arrive at a general solution of the problem. We say that the solution remains the same when the law of expansion and compression is represented by an equation of the form of $P\,v^m =$ constant.

In fact, let us suppose we have:

For the curve A M B: $x^m\,y = \text{const.}$

" " C N D: $x'^m\,y = \text{const.}$

Thence we shall also have:

$$x\,y^{\frac{1}{m}} = v\,P^{\frac{1}{m}}$$

$$x'\,y^{\frac{1}{m}} = c\,v\,P^{\frac{1}{m}}$$

$$(x + x')\,y^{\frac{1}{m}} = X\,y^{\frac{1}{m}} = v\,(1 + c)\,P^{\frac{1}{m}}.$$

$$\text{Or, } X^m\,y = P\,v^m\,(1 + c)^m = \text{const.}$$

The curve, A T R, is then, in this case also, the curve of the pressures during the expansion, and, if what we stated above be true, the areas, D C A T R D and I C A B I, are equal.

To sum up, if the final pressure is equal to the back pressure (that which corresponds to the maximum of power given out); if the compression is such that at the end of the stroke the pressure of the steam enclosed in the dead space be equal to the pressure of admission; if the law of expansion is the same as the law of compression; we shall obtain from a given volume of steam the same power as if there had been no dead space in compression, as is stated above, provided that the original capacity of the cylinder be increased by the volume produced by its diameter multiplied by the distance traversed by the piston from the time the compression commences to the end of the stroke.

We believe that this fact has never before been enunciated.

Objections.—As regards the compression of the back pressure steam, it may be objected that, to ensure the same regularity in working, a heavier fly-wheel will be required. This objection is not without foundation, but it will be useful to estimate the amount of loss which will result from the adoption of a heavier fly-wheel; and to this end let us take an example where the conditions are very unfavorable to compression.

Let us compare the weight of the fly-wheel of an engine theoretically perfect, without dead space and without compression, with that of an engine with a considerable amount of dead space—for instance, 0.15 of the volume of steam admitted, and expending the same volume of steam for the same power per revolution. In the two cases, the pressure of admission will be five atmospheres, that of the exhaust one atmosphere; the steam is cut of at a fifth of the stroke in the former case, and the length of the connecting rod is five times that of the crank. For simplicity, we suppose that the strokes are equal, and that the increase of volume in one case is due only to the diameter of the cylinder being larger, which in no way alters the conditions of the problem. As no question is raised but one of comparison between the two engines, we will suppose that during expansion the pressure follows Mariotte's law. We have, in this instance, made use of diagrams as well as formulæ, but the reproduction of our drawings involved too many difficulties, and, in fact, presented too little general interest, to lead us to undertake it; we will, therefore, content ourselves with giving our results.

In a revolution, the effect of the resultant of the forces is negative at the two dead points. If a vertical engine be under consideration, we will call A the negative force of the resultant at the dead point corresponding with an upright position of the crank, when the piston has reached the top of the cylinder; C, the negative force at the lower dead point; B, the positive force exerted between A and C; and lastly, D, the positive force exerted between C and A. By the index 1, we designate what relates to a case where there is no compression; and by the index 2, to a case where there is compression. We have calculated the forces in square millimetres in accordance with our diagrams, and find the power given out in a revolution with mean resistance

$$:S = 6664;$$

then

$$\left.\begin{matrix} A_1 = 1521 \\ C_1 = 1288 \end{matrix}\right\} A_1 + C_1 = 2809$$

$$\left.\begin{matrix} B_1 = 1316 \\ D_1 = 1493 \end{matrix}\right\} B_1 + D_1 = 2809$$

$$\text{Maximum force } A_1 \text{ and } \frac{A_1}{S} = 0.22824.$$

$$\left.\begin{matrix} A_2 = 1774 \\ C_2 = 1555 \end{matrix}\right\} A_2 + C_2 = 3329$$

$$\left.\begin{matrix} B_2 = 1557 \\ D_2 = 1772 \end{matrix}\right\} B_2 + D_2 = 3329$$

$$\text{Maximum force } A_2 \text{ and } \frac{A_2}{S} = 0.26621.$$

From this it will be seen that the flywheel of the engine with compression is 16.6 per cent. heavier than the other. This increase of weight gives rise to an increase of friction when the engine is running without load. Now in the normal working of the engine, 9 per cent. can be taken approximately as representing this friction, and it is an exaggeration to attribute 4 per cent. of this to the friction caused by the weight of the flywheel. To sum up, the compression might cause a loss of nearly 0.66 per cent., while it effects a gain of about 5 per cent. of the weight of steam used. A considerable balance, therefore, remains in its favor, which engine manufacturers cannot neglect. Thus, then, falls to the ground the objection made to compression on account of the increase in the weight of the fly-wheel.

Compression is preferable to complication of the valves.—But since, as a matter of fact, the use of compression requires an increase in the size of the cylinder, it is requisite to reduce, as far as possible, the dead space. Now the exhaust passages should be larger than those of admission; for all strangling of the steam at exhaust is a dead loss, while strangling the steam at admission involves no loss at all, the weight of steam expended diminishing with the force produced. If, then, it is advisable to place the steam ports at the ends of the cylinder, it is not less advisable to separate the admission from the emission, and to work the latter by means of two special ports placed at the ends of the cylinder. This is, to a certain extent, a complication, but it seems to us a necessity. What we consider inadvisable is to increase this complication still further in order to reduce the loss due to the dead space, which is, in fact, a small matter; while, without adding to, or detracting from, the valve arrangement, this loss can be suppressed entirely by the method of regulating the distribution of steam. Undoubtedly, it will be said, but an increase in the dimensions of the engine will be found necessary, and consequently, an increase in its friction will ensue. It does not appear to us that this increase need be very large. The engine requires about 9 per cent. of the useful power exerted to run without load; now, in the extremely unfavorable case we supposed in the first place, the volume of the cylinder with compression is 60 per cent. greater than the volume of the cylinder without compression and without dead space. But the friction of the valve gear only augments in proportion to the cube root of the volume of the cylinder. The increase of friction will only be about 17 per cent.; that is to say, instead of 9 per cent. of friction, there would be 10.6 per cent. The compression would have caused a gain of more than 10 per cent., and the increase of volume a loss of 1.6 per cent., leaving a clear gain of 8.4 per cent. obtained without the least complication of the valve gear of the engine.

Besides, it is a well-known fact that engines, as generally constructed, are designed so much in excess of the power required as to admit of compression without an increased capacity of cylinder. In fact, this is what frequently occurs; a manufacturer, who, foreseeing an increase in his business, wishes to be supplied with a steam engine, invariably orders it for a greater power than he really requires; and the engine maker, in order to give satisfaction to his customer, and to avoid tedious calculation, and any chance of insufficient power, gets out his cylinder with exaggerated co-efficients of reduction, such as 50 and even 40 per cent. So that while a power of 15 horses would suffice, the manufacturer orders 20, and the engine builder gives 30, or double what is necessary.

Such a method of proceeding gives rise to prejudicial effects as regards regularity of motion and also economy of working, both of which it is expedient, from all points of view, to correct when it is not possible to avoid them altogether. To make use of a powerful engine to do some trifling work amounts to the same thing as putting a horse to draw in a cart a few kilogrammes which a child might easily carry. The friction inherent in an engine working without load takes up, let us suppose, 20 out of the 200 horse-power which the engine is capable of giving out, or in other words 10 per cent. But if the engine have only a load of 90 horse-power, it no less requires the 20 horse-power to run, and the loss on this account is 40 per cent., without reckoning all the losses arising from the larger surface exposed to radiation of heat.

Although their engines are designed in excess of the work, most manufacturers require that the pressure in the boiler shall be kept up to that originally calculated, maintaining that high pressures are the most economical. Undoubtedly they are, when the load is in due proportion; but not when it is much below the power of the engine. In fact, if the expansion is variable by the governor, the pressure during admission is equal —or very nearly so—to that in the boiler; but the admission will be much smaller than was expected; the fly wheel will be found too light; the governor will encounter new difficulties; there may also result very considerable jars at the beginning of each stroke (especially if there be no compression and no lead given to the valve), jars which are, like blows of a hammer, sufficient to hard-beat the plummer-block brasses, thus considerably increasing the expense of maintenance, repairs, and renewal.

The effect is still more damaging in engines the governor of which acts on the throttle-valve, and in which the expansion is fixed and very great. This will readily be seen by reference to fig. 3, in which are reproduced some diagrams taken by us from an engine of 80 nominal horse-power, but capable of working up to 160, and which only had a load of about 50 horse-power. The cubical content occupied by the steam between the throttle-valve and the steam ports was very small in comparison with that of the steam-chest. The steam was cut off at about a quarter of the stroke. During the remaining three-quarters, as no steam was admitted into the cylinder, and as the throttle-valve did not entirely close the pipe, there was necessarily an admission of steam into the latter corresponding with the amount that the throttle-valve was open, so much so that, at the commencement of each stroke, the steam contained in the space between the throttle-valve and the ports was at the same pressure as that in the boiler. During the admission of steam, this pressure gradually became lower, and a partial expansion was produced; but when the pressure was much too high, five atmospheres for instance, the impact of the steam on the piston was terrible—about 22,000 kilogrammes (48,506 lbs.), and the total pressure fell almost suddenly to 13,500 kilogrammes (29,765 lbs.). When, however, the pressure was lowered gradually, the diagram, during admission, became more and more horizontal, as shown by fig. 3, and the result was the discontinuance of the blows and a great saving of fuel.

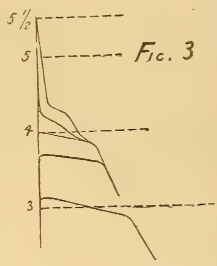


Fig. 3

If, by the compression, we diminish

the difference between the power really exerted by the engine and that which it is capable of yielding, and if, at the same time, we diminish the boiler pressure, whenever that may be necessary, the motion of the engine becomes sweeter and more regular, and its working more economical. Agreeably with the expansion, the compression has the effect of gradually reducing the *vis viva* of the piston, and therefore of preventing the piston rod from being lengthened or shortened. This effect is the more manifest as the load on the engine is greater; it increases, also, as the square of the speed. If it be wished to diminish this as much as possible, while at the same time adopting a high piston speed, the piston should be made as light as possible. This is the reason which led Allen to make use of very light pistons, the body being forged in one single thin piece, and the raised edge furnished with grooves to receive the Ramsbottom rings. Notwithstanding these precautions, the diagram of the Allen engine showed that there was a considerable compression, which has been most unaccountably suppressed in the Corliss engine; the pistons of the latter are, however, stouter.

The compression of the exhaust steam offers, then, some considerable advantages, which it will be advisable not to pass over. Now, as to the degree of compression which it is best to adopt, if the initial pressure of admission has been determined once for all, the degree of compression should remain invariable; if the initial pressure varies, it is better also to vary the degree of compression; the rule is that the steam enclosed in the dead space should have, at the end of the stroke, a pressure exactly equal to that of admission.

This is never the case with engines in which the governor acts upon the throttle-valve; whence it follows that this system of governing is not generally advisable, and that the Allen and Corliss engines have an advantage over others, which has, unhappily, been lost sight of until the present time. The exhaust valves of these latter might be regulated for the compression, without in any way changing the arrangement of the valve rods; and as the pressure at admission, which is always high, is in this case constant, the best conditions are obtainable.

A little lead in the exhaust gives facilities for emission at first; but this lead is just so much less beneficial as the pressure at the end of the expansion approaches that in the condenser.

It is a rare circumstance to find the diagrams of the Allen or Corliss engines show the least advance in the exhaust; in their cases it is replaced by a sharp opening of the exhaust ports, due to the cinematic arrangement of the valve gear. In the same way that a long expansion renders useless an advance in the exhaust, a long compression renders useless an advance in admission, provided that the port be opened sharply, the piston speed being high. The ideal diagram of a steam engine would, therefore, assume the form which we indicate by D C A T R D in fig. 2. It is approximately that of the Allen engine, which was shown at the London Exhibition in 1862. The diagram of the Corliss engine, however, differs from it considerably.

Improvements to be introduced.—Before bringing these prefatory observations to a close, let us be permitted to say a few words on the extent of the saving which certain engine builders sometimes promise. The principal points to which attention should be drawn, when the subject of economy is raised, are the following:

1. Imperfect circulation.
2. Imperfect expansion.
3. The difference between the boiler pressure and that of admission to the cylinder.
4. Excess of the back pressure over the pressure in the condenser or of the atmosphere; and the excess in the temperature of the steam over that of the cold water.
5. The friction of the engine when running without load.
6. Additional friction of the engine due to useful load thereon.
7. The necessity of feeding the boiler.
8. The loss by radiation of heat in all the steam pipes leading from the boiler.
9. Steam jacketing.
10. The superheating of steam.
11. Speed of the engine.
12. The boiler.

Let us see how the arrangements for admission and emission of steam can reduce the causes of loss in engines.

1. Zeuner calculates that, according to the hypotheses which are generally made as to the action of steam in the cylinders of our engines, the loss arising from the imperfection in the circulation, with 10 per cent. in weight of water in the steam at the moment of admission, might vary from 19 to 8.6 and 4.9 per cent., according as the temperature of the feed water was 15°, 80°, or 100° Centigrade, the engine being a condensing one; whence is conceived *the advisability of utilizing the waste heat to reheat the feed water, while at the same time adopting the principle of condensation.* The calculation shows further that the loss arising from the imperfection in the circulation diminishes in the same proportion as the water contained in the steam diminishes; whence follows the advisability of drying the steam, but the gain arising from this is only slight.

By admitting that the steam contains 15 per cent. of water at the instant of admission, and that the temperature of the feed-water is 80° Centigrade, it is found that the loss arising from the imperfection in the circulation is about 8.8 per cent., which is reduced to 7.7 per cent. by thoroughly drying the steam, but which the changes in the pressure diagram, owing to the conditions of admission and emission of steam, could not reduce by a quarter per cent.; in fact, might even increase by a too great difference with the hypothetical diagram.

2. An imperfect expansion is a cause of loss which the arrangement of the engine might considerably reduce. The maximum power given out corresponds with a final pressure equal to the back pressure. In a condensing engine at five atmospheres, the loss under this head might be reduced to about 11 per cent., but to accomplish this the steam should be cut off at the thirty-first part of the stroke, which would require a cylinder of immense size, 56 cubic metres per horse-power per hour, while an engine working at full pressure would only require 5.9 cubic metres, and an engine with 4.68 expansion only 11.75 cubic metres. This last named degree of expansion would give nearly the minimum consumption of fuel and cost of sinking fund at the same time. But then, the loss arising from the imperfection in the circulation rises to about 32 per cent. If the engine builder, by the arrangement he adopts, is able to reduce the expense of the sinking fund, at the same time that he increases the degree of expansion, he is quite in a position to construct an engine which shall be both cheap in itself and economical in its working at the same time. Thus, by a cut-off at only one-tenth of the stroke, a loss, due to the increased expansion, of not more than 20 per cent., is incurred, only 4.905 kilogrammes (10.814 lbs.) of feed-water, per horse-power per hour are used, and consequently there is a gain of 12 per cent. It is true that the volume of the cylinder, which was 11.75 cubic metres, has now become 20.67 cubic metres, or nearly double. If the engine builder has found that he can construct an engine with cylinder of 20 cubic metres volume as cheaply as one with cylinder of 11 cubic metres, he has solved a famous economical problem. Nevertheless, in reality, the saving is less, on account of the necessity of regularity in the speed of the engine. In fact, if the resistance varies, the admission of steam must vary, and thus the circulation differs more or less from the maximum of power.

To sum up, then, with reference to the first two points, the engine manufacturer might regain about 12 per cent.; and if 8 per cent. be added on account of back-pressure steam, we arrive at 20 per cent. But let us remark that this compression can be obtained, whatever valve-gear may be employed.

3. The difference between the pressure in the boiler and that of admission depends on a variety of circumstances, among which we will point out the guarding against radiation of heat, the length of the pipes, the temperature of the steam and that of the outer air, and the dimensions of the steam ports. With the greatest precaution this loss might be reduced to 2 per cent. without any change taking place in the arrangements for admission and emission of steam.

4. The loss by excess of back pressure over the pressure in the condenser might be reduced, by ordinary means, to about 3 per cent. Let us repeat, however, what we said before, that increasing the dimensions of the ports has the objection of increasing the dead space. The loss arising from excess of temperature of the steam over

that of the cold condensation water exceeds 15 per cent.; but it is inseparable from the whole system of condensation, and relates in no way to the admission and emission of steam in the cylinder.

5. Zeuner estimates the friction inseparable from the engine when working without load at 2.8 per cent. We are inclined to think that this figure is much too low, and that it would be better to raise it at least to 8 per cent., below which it cannot be brought by the most exact erecting and the best keeping in repair, combined with the greatest possible lightness of the working parts. Under this head the system of admission and emission has but a slight influence; it is the friction of the piston and that of the main shaft which account for very nearly the whole loss on this account.

6. The amount of additional friction of the engine due to the useful load thereon, etc., depends especially on the exactitude with which the parts have been fitted, and the state in which the surfaces working against one another are kept. Zeuner estimates it at 8.5 per cent.; but, according to experiments made with a dynamometer, on some powerful engines, this figure appears in excess. However, as in this place we are only dealing with generalities and means, we will adopt the 8.5 per cent. to arrive at our conclusions.

7 and 8. The necessity of feeding the boiler constitutes a loss of power (as radiation does of heat), which the engine-builder should reduce as far as possible; but these losses are unconnected with the system of admission and emission.

9 and 10. The steam jacket and superheating the steam constitute means of saving, the amount of which experience alone can teach, but which are not connected with the special system of the distribution of steam in the cylinder.

11. The system of the distribution of steam has no more influence than that we have stated upon the speed of the engine, on which, however, depends, for the most part, the actual power given out, or the useful work, as measured by a dynamometer. In fact, according to the number of revolutions effected by a given expenditure of motive power per hour, the useful work varies between zero and a maximum of value. In comparing, therefore, one engine with another, it must always be taken for granted that the speed of each is that which corresponds with its greatest useful power; and when two systems are compared, to make allowance accordingly.

12. The influence of the boiler on the consumption of steam by the engine is almost *nil;* two boilers, therefore, supplying steam at the same pressure to an engine which expends a given quantity, can only be compared with regard to the amount of coal they consume in generating this steam. Inasmuch, then, as we desire to estimate only what is at the disposal of *the constructor of the engine,* we must disregard the boiler, and have regard *only* to the *weight of steam* expended per horse-power per hour.

To sum up, supposing the engine so arranged as to nullify the effects of the dead space; supposing the circulation to be as little imperfect as possible; the temperature of the feed water 80 deg. Centigrade; and the cut-off at a tenth the stroke; without taking the radiation of heat, etc., into account, but including the losses under other heads, we arrive at an actual power given out of about 50 per cent., and a consumption of 7.848 kilogrammes (17.266 lbs.) of water per horse-power per hour. In our opinion, the engine constructor could not economize under this head by more than 9 per cent., and consequently, reduce the consumption of water to 7.142 kilogrammes (15.712 lbs.); this, too, at the risk, perhaps, of considerably increasing the expense of maintenance and sinking fund.

We conclude from the above that while the constructor of an engine without steam jacket, without superheater, and working under the aforesaid conditions, has not lowered the consumption of water to 7.142 kilogrammes per horse-power per hour, it is not so much to the distribution of steam in the cylinder that he must pay attention as to the other points on which the economical working of the engine depends. We therefore regard as rash and very dangerous such proposals as that made by one exhibitor, viz., to replace by his own any other engine whatsoever, at his own expense, on the sole condition of having, during twenty years, half the profit gained.

In the conditions which we have just examined, the expenditure of heat per horse-power per hour would amount to

4,489 calories. But if the coal used were pure and capable of giving off 8,147 calories per kilogramme (2.2048 lbs.), the minimum of expense connected with the boiler would be 0.551 kilogrammes of pure coal per horse-power per hour. But it is impossible to obtain for the boiler, as it is for the engine, its maximum theoretical return. This is about 14.25 kilogrammes of water turned into steam at from 80 to 150 deg. Centigrade, per kilogramme of coal minus the ashes and all waste. A boiler which gave a return of 75 per cent., or which supplied 10½ kilogrammes of dry and saturated steam per kilogramme of coal consumed, would be considered a very good one. It is a rare circumstance for a stoker, even an experienced hand, to exceed 9 kilogrammes, which corresponds to a return of about 0.65 per cent.

Under conditions which we consider exceptionally favorable, we are enabled to reduce to about 0.8 kilogrammes the consumption of coal per horse-power per hour. The constructors of the Corliss engines usually guarantee 1.2 kilogrammes, allowing for 10 per cent. of residuum, and experiments prove that some engines do not consume more than 1 kilogramme. There will be a difference, then, of 0.2 per horse-power per hour, or about 600 kilogrammes annually; at 0.03 fr. per kilogramme, the saving, therefore, will be 18 fr. per horse-power per annum. If the half of this returns to the constructor in the shape of payment for his engine, he will have 9 fr. per horse-power, say 270 fr. (10 guineas) for an engine of 30 horse-power. An annuity of 270 fr. during twenty years is equivalent to about 3,230 fr. (£127) paid down at once, with the supposition that the annuity was to continue in perpetuity. Truly, this is not a remunerative price, and the proposal, to which we have alluded above, appears to us devoid of sense.

SANITARY ENGINEERING—RETROSPECT FOR 1874.

From "Engineering."

In attempting to give a summary of the various phases of sanitary progress during the past year, we may commence by stating that more active interest in each department of sanitation has been observed than during any previous year. The lull in political matters, the general prosperity of the country, and other causes, have all combined to produce this favorable result. The public mind had in fact been sufficiently calm to weigh many of the most important questions relating to sanitary science, and local prejudices and personal interests have been frequently given up for the general public good. By reference to the index of our last and preceding volumes there will be found the names of a large number of subjects that we have taken up for description and discussion. In these articles our readers will find the details of many important inventions, improvements, and suggestions all tending to the solution of many of our sanitary and analogous social problems.

As might be expected, the most important question of the year has been that interminable difficulty, the *Disposal of Sewage*. For all practicable purposes we cannot perceive that the question is any nearer solution than it was when we gave our Sanitary Retrospect for 1873. Perhaps the most hopeful sign of last year was that afforded at the Conference of the Society of Arts, held on December 10, and fully reported in *Engineering* in the following week (see page 480 in our last volume). But the meeting referred to, which had for its object a discussion of the "Pollution of Rivers," ended in no further result than a general vote acknowledging existing evils and the necessity of remedy. No feasible plan was suggested for the disposal of fæcal matter, house refuse, manufacturing waste, etc., as now allowed to enter most of the rivers and small streams of Great Britain. The only methods of treating water-carried sewage so as to purify it before discharge into rivers, that were suggested, emanated from companies or individuals personally interested in the matter.

Without here naming them, it may be briefly stated that so far as we have been able to gather information that we could rely on, not one company formed for disposal of and utilizing sewage has yet succeeded in showing a favorable balance-sheet; on the contrary, by referring to the daily share list their stock is at a heavy discount, and in more than one case actual breakdown has only been prevented during the past year by the forbearance of the shareholders, or by subscription of additional funds to supply the loss of the entire original capital, as was the case with the Native Guano or A B C Company. Towards the close of the year the Phosphate Sewage Company commenced actual work with the sewage of Hertford, and when their operations are more advanced we shall draw attention to them in practical detail. General Scott's lime and cement process seems to have resulted favorably; but at present, as with all the chemical precipitation methods, it is only in a tentative condition. The various other schemes for sewage disposal now at work are equally experimental in their character. Mr. Hope can alone furnish an excellent specimen of irrigation results on the large scale; thanks to his perseverance and extended agricultural knowledge. Examples of minor successful results may be found at Aldershot, Croydon, and at the Earl of Warwick's farm, near Leamington. The great difficulty of getting land near large towns is a serious obstacle to irrigation farms. In some cases Mr. Bailey Denton's method of intermittent downward filtration has succeeded, and we think it probable that, during the present year, its use will be much extended.

In regard to the legislation of the past session, two important Acts were passed —one having for its object the amendment and extension of the Public Health Act of 1872, and the other, the repression of certain noxious trades in the metropolis, or at all events their regulation in regard to the mode of their being carried on. The Sanitary Laws Amendment Act, just alluded to, has for its object to bring a certain amount of pressure on local authorities previously remiss in their duties, the performance of which may now be enforced by writs of *mandamus*. Provision is also made that every urban authority, when required by the Local Government Board, shall at once take steps for the proper cleansing of the streets, the removal of house refuse, etc., under heavy penalties in case of neglect. Power is given for the purchase of buildings, dams, weirs, etc., which may hinder efficient sanitary measures being carried out; public and private wells affording polluted water may be stopped. Other excellent provisions are contained in the Bill, which, however, can after all be only considered a piece of patchwork legislation. A semi-official statement was made, however, toward the close of the year, that the Government intended, during the next session of Parliament, to introduce a comprehensive scheme especially dealing with the pollution of rivers by sewage. About the same period Sir John Hawkshaw was appointed a special Royal Commissioner to examine into and report on the state of the Clyde. It is highly probable that his report may to a large extent become the basis of future legislative action, the reports of the Royal Rivers Pollution Commissioners being also taken into account.

Next to and of equal importance is the question of the *Water Supply.* This excited great attention during 1874, owing to a variety of causes. The first half of the year was noted for its extraordinary drought, not much more than half the usual rain having fallen during that period. Consequently, with the exception of London, Glasgow, and Manchester, every town and village suffered from deficient supply. In some cases the latter was entirely restricted to the purpose of absolute domestic want. In many of the largest towns, had an extensive fire broken out, it would have been impossible to have extinguished it from want of water. Many schemes were brought before Parliament for improved water supply, and several bills were passed that perhaps would have otherwise been delayed to another session had not imminent necessity stimulated our legislators. It unfortunately too frequently happens that unless some sudden calamity springs up, our national lethargy in regard to many social matters gives rise to dangerous delays. There is no doubt that our rainfall is infinitely greater than sufficient to supply all our wants. We need not, however, here enter into a discussion of this point. This has been fully done in an article on "Water Supply and Storage," at page 284 in our last volume, in reference to the metropolis and provincial cities. We would especially draw attention to the estimates of Mr. Bailey Denton in respect to our natural sources of water given at page 285, where some valuble statistics are afforded showing the enormous resources at our command.

But besides quantity, the quality of our present water supply was much the subject of discussion during 1874. To a very large extent our towns are supplied by rivers receiving the sewage of places during their whole course. The metropolis is thus circumstanced, nearly the whole of the southern supply being drawn from the Thames above Teddington, where the tidal flow ends. Toward the close of 1864 strong complaints were made against the supply by the Chelsea Water Works Company for the turbidity of the liquid. During the last three weeks in December the New River water, while clear, presented occasionally a brown tint, although in this case extensive filter beds are in constant operation. Of course Glasgow and Manchester maintain their former reputation for excellent water, simply because the supply for either is drawn from sources incapable of contamination.

Towns are not the only sufferers in regard to water. In many small places in Great Britain, and even in some moderate-sized towns, the supply is almost exclusively derived from public and private wells. The soil adjacent to these being porous allows of the infiltration of polluted water from adjacent sewers, privies, etc. A large amount of typhoid disease was traced directly to such sources during 1874, and in some cases immediate steps were taken to abate the evil. One great object of the Sanitary Laws Amendment Act was to provide for such cases; but unfortunately the Bill could not point out how water could be obtained. In this as in many other cases, therefore, necessity becomes law, and so, for a long time to come, the inhabitants of small towns, etc., will have to drink impure water, because none other can be obtained. It is thus evident that the sewage and water question must, necessarily, be dealt with together in any comprehensive scheme of sanitary legislation. In reference to the sanitary reform of our villages, we would refer to remarks on that subject given in our issue of November last, at page 367, in the form of a paper read by Mr. James Howard, of Bedford, before the Farmers' Club.

Without entirely adopting the death-rate as a test of the sanitary condition of a town, we yet cannot but consider it as a very important indication. An instance of this will be seen in an article on "The Disposal of Sewage, etc., at Rochdale," at page 488 in our last volume. Referring, however, to the Registrar-General's report, published weekly, we find that temperature, rainfall, etc., have most important effects. For the purpose of illustrating such causes on public health, we shall select two periods during the year 1874. The early portion, in fact almost toward the close of the year, was characterized by only moderate changes of temperature, and but moderate rainfall. But, in December, a most severe winter set in, one, in fact, that had not been experienced for upward of a dozen years previously. We select, for our purpose, the second week in August as a summer month, and the third and last week in December as a winter month.

From the Registrar-General's return for the week ending August 15, the mortality from all causes was at the average rate of 26 deaths in every 1,000 persons living. The annual death-rate was 19 per 1,000 in Edinburgh; 27 in Glasgow; 27 in Dublin; and 21 per 1,000 in London. Temperature at Greenwich averaged 58 deg.

But from a similar return for the third week in December, the mortality from all causes was at the rate of 31 deaths annually in every 1,000 persons. The annual death-rate was 31 per 1,000 in Edinburgh; 50 in Glasgow; 27 in Dublin; and in London 25 per 1,000. The temperature nearly averaged 32 deg., often falling to 25, and once to 18 deg.

During the last week in December the death-rate was still higher. The mortality from all causes was at the average of 41 deaths annually in every 1,000 persons living. The annual death-rate was 42 in Edinburgh; 60 in Glasgow; 45 in Dublin; and 37 in London. The increase was almost entirely due to diseases of the respiratory organs. The mean temperature of the air at Greenwich was 28.8 deg., or 8.5 deg. below the average of the

50 preceding years. The lowest temperature was 18.5 deg.

Now, it is evident from these two instances that a great variation in temperature must largely invalidate the death-rate as a test of good or improved sanitary conditions. A low temperature carries off rapidly those affected by diseases of the lungs, etc., while it diminishes the danger arising from typhoid diseases; while an increase of temperature favors the latter, and lessens those of the kind dependent on affections of the respiratory organs.

During the last and preceding years much attention has been paid to the evil sanitary results arising from *Atmospheric Pollution* in our manufacturing districts, arising from gaseous matter and dust resulting from chemical and other manufactories. To these questions we have devoted several articles in our last volume. Hitherto little attention has been paid to this important point, but the reports of Dr. Angus Smith in respect to the working of the Alkali Act, and the reports of several of the Factory Inspectors have brought to light several causes of disease not hitherto isolated in respect to their causes. The action of metallic vapor, etc., in mining and smelting districts has also been shown, during the past years, to have a very important influence in determining the health of such localities. Some very interesting investigations have been carried on in Germany in respect to this subject, accounts of which appeared in the report of the Local Government Board (England), published last July.

The subject of *Overcrowding* engaged much attention throughout England during 1874. The reports of medical officers and others disclosed a state of things which, whether in regard to physical or moral considerations, are a disgrace to civilization. In many places the so-called houses were worse than ordinary stables. As many as ten persons of all ages and both sexes have been seen huddled in one "cottage," consisting occasionally of two small rooms, but in many instances of one room alone. Nothing can tend more effectually to the production and propagation of zymotic diseases than this state of things. Public attention was specially drawn to the subject during 1874 through an outbreak of small-pox at Newmarket, but which was only a type of scores, if not of hundreds, of other places. It is to be hoped that this overcrowding will become the subject of legislation during the ensuing session.

Closely connected with this is *Ventilation*. This subject seems of late years to have almost escaped attention. In an article in our last volume we pointed out glaring instances of bad ventilation, as, for example, in the Houses of Parliament, the Reading Room of the British Museum, etc. Private houses are seriously defective in this respect; hence all the evils of overcrowding among the lower classes are introduced into middle-class houses, although, perhaps, in a modified form.

Our means of artificial illumination might be made frequently of great service in improving ventilation in public and private buildings. This leads us here to notice the serious increase in the price of gas which occurred during 1873–'74. In our last two volumes we have entered into a full discussion of the so-called gas question, and shall therefore only refer to our articles on the subject. It is satisfactory to know that in the present year the price of gas will be generally lowered.

Such is a summary of some of the most important points which arose during 1874 in regard to sanitary matters. It is satisfactory to find that public health is now the most prominent of all questions before corporations and local boards throughout the kingdom. It is true that their full discussion has been much tinctured with party feeling and local prejudices. But all these and many other difficulties may be promptly overcome by comprehensive legislation. We sincerely hope that during the next session of Parliament the Government will take the matter boldly in hand. Plenty of information exists in regard to the facts of the case, and it now only remains to use those facts in such a manner that the exigencies of public health may be fully satisfied. The question must be treated in a national point of view, and from no party aspect.

A RECENT test of the relative strength of oak and Oregon pine, made at San Francisco, with bars each 1 in. square and 3 ft. long, showed that the pine was equal to the oak. Both broke under the same weight placed in the middle of each bar, namely, 260 lbs.

APPLICATIONS OF THE GYROSCOPE.

In our February number we quoted an article from *The Nautical Magazine* treating of Mr. Bessemer's proposed application of the gyroscope to the working of the "regulating valves," by which hydraulic gear controls the relative motion of his "suspended saloon." (For full account of which see *Engineering*, October 9, 1874). We do not propose to comment upon the purely technical part of that discussion, quite adequately given in the article in question, but to refer to some theoretical matters.

Mr. McFarlane Gray (*Engineering*, October 16, 1874) announces that the apparatus has "nothing gyroscopic about it, and will act just as well without rotation as it will do when making 5,000 revolutions per minute." In another communication (*Engineering*, October 30, 1875), he adds, "Mr. Bessemer has only to turn his gyroscope round a quarter of a circle to bring the trunnions *across* the saloon; it will then act very well by the unsteadiness of the gyroscope according to my patent, instead of the unsteadiness according to his patent." And Mr. Gray gives a formula for the "moment of the couple" exerted *laterally* when an angular motion is given to the *axis* of a rotating gyroscope. Most of our readers are familiar with the peculiar forces which the gyroscope develops under such circumstances; all can be, by holding the ring of a common gyroscope at points near the opposite ends of the axle, with the two hands, and *giving angular motion* (*i. e.*, change of direction), to the axle. This "couple" is, according to Mr. Gray, equal to

$$\frac{W u v}{2 g}$$

in which W is the weight of the wheel, v and u the "lineal velocity of rotation" of the disk and the "lineal transverse" angular velocity of its axis, both "measured at a distance from the axis of the trunnions" (from their *respective* axes, is probably meant), "equal to the radius of gyration of the disk about its running axis."

The Nautical Magazine states that, "so far as we are aware, the first example of direct calculation of gyroscopic effect as an engineering quality," is due to Mr. McFarlane Gray, and made in relation to strains resulting from rolling and pitching on the shafts of fly-wheels attached to marine engines. We do not question the above dictum, but remark that so long ago as 1831 Prof. W. R. Johnson, of the University of Pennsylvania, who may be justly styled the real inventor of what has since been known as the "Gyroscope" (the Bohnenberger machine, its only predecessor, intended simply to illustrate the precession of the equinoxes, exhibits little of the "paradox" to which the gyroscope owes one of its appellations), comments (*Am. Journal of Science*, January, 1832), on the "powerful effort" made by the fly-wheel common to the steamboat engines then in use, "to depress one and elevate the other of its gudgeons," and that a corresponding effect in racking the boat or causing it to careen is produced, whenever the vessel, in its progress, sharply rounds a curve. But the fly-wheel is practically unknown to ocean steaming, and has almost disappeared from inland navigation.

As to a complete solution "of all the paradoxes of the gyroscope," we believe that the first *complete* solution—and to this day the most thorough formalized solution of the "Phenomena of the Gyroscope"—is that of Major J. G. Barnard, Corps of Engineers, U. S. A., which appeared in the *Am. Journ. of Science*, and Barnard's *Am. Journ. of Education*, in 1857, and which was issued in a pamphlet form, in 1858, by the publisher of this Magazine. General Barnard has since (Vol. xix. Smithsonian Contributions), deduced from his gyroscopic theory the otherwise known formulæ for the Solar and Lunar "precession" and "nutation" of the earth's axis; and has for the forthcoming second volume of Johnson's New Cyclopedia condensed the theory and given the history of gyroscopic applications and inventions.

We call attention to the formula (h)

(of the Journals first cited, or of Van Nostrand's pamphlet edition), for what the author styles the "deflecting force, g'."

$$g' = \frac{C}{\gamma M} n v$$

Multiplying by γ (the lever arm), and M (the mass of the disk), we get for the "couple," the expression

$$C n v$$

in which C stands for the "moment of inertia" of the disk, n its *angular velocity*, both with reference to the axis of figure; and v the angular velocity of that axis. But if W be the weight of the disk, and k its "radius of gyration about its running axis," and g the force of gravity, we shall have

$C = M k^2 = \frac{W}{g} k^2$, and the above becomes

$$\frac{W}{g} k^2 n v \qquad (a)$$

But $k n$ and $k v$ are precisely the "lineal velocities," v and u, of Mr. McFarlane Gray. The "couple" is, therefore, (expressed in *his* symbols),

$$\frac{W}{g} u v$$

In his communication to *Engineering*, already cited, he has undoubtedly written by inadvertence, $2g$ for g; at any rate, the correct value of the couple is as we have just deduced it from General Barnard's analysis.

That analysis fully sustains Mr. McFarlane Gray's dictum (quoted in our second paragraph) concerning Mr. Bessemer's contrivance. It announces that "with a force so applied as to prevent any deflection from the plane in which gravity tends to cause the axis to vibrate, the motion would be precisely *as if no axial rotation existed.*"

The bearing axle (with "trunnions") of the "casing" in which the Bessemer gyroscope is mounted, lying in the direction of the vessel's length, prevents any "deflection" from the transverse plane (of "rolling"), and (except to "pitching motion," to which it has no reference) the gyroscopic character of the instrument is nullified. Mr. McFarlane Gray's plan is to place this axle *crosswise*. "Rolling" motion will then generate a "deflecting force" (as styled by General Barnard), under the action of which the instrument is free to move, for the "moment" of which a formula has just been given. Let us try to make some practical estimates. Observations made in the ship Norfolk (*Engineering*, Oct. 30, 1874) give, as the *average* angular *rolling* velocity for a voyage of 2,026 hours, $2\frac{1}{2}$ degrees of arc per second of time. Taking 300 lbs. for W, 1.75 ft. for k, and 458 ft. per second for v (corresponding to 5,000 revolutions per minute), and 0.002 ft. per second for u (which results from $2\frac{1}{2}$ degrees of arc per second *rolling* velocity), formula (a) gives 8.3 as the measure of the "couple"—that is, a force of 8.3 lbs. would be exerted at a distance of one foot from the "trunnion" axis. But the object is to *suppress* rolling motion; the *average* rolling motion of a ship at sea would be quite inadmissable. Will a fraction of this force work the valves, besides overcoming friction of trunnions, etc.? Will even this *eight pounds* generated by *average* rolling be adequate?

We hesitate in answering even the latter query affirmatively and in assenting to the opinion that by the "unsteadiness of Mr. McFarlane Gray's arrangement the machine will act very well;" the unsteadiness being dependent on the very "rolling" motion it is designed to suppress and requiring, too, an amount of that motion likely to be very appreciable to the sensitive stomachs for the benefit of which solely the "suspended saloon" is devised.

In either arrangement *pitching* motion is left out of view entirely. Whether or not it is expected the vessel will be absolutely free from it we do not know; but, so far as it exists, it is unpalliated by the Bessemer saloon, and will, when violent, under either "patent," exert a certain effect upon the controlling valves (in Mr. Gray's patent by *inertia* merely).

As to this, or other, "useful applications" of the gyroscope, we have little faith in any depending on the *permanent* running of a gyroscopic machine, even if such elaboration of mechanical arrangements and the use of hydraulic power to effect it, were sure to be entirely successful, and were always admissable.

But the difficulties are of too abstruse a character for discussion here. The *perfection* of application of the gyroscopic principle is found in rifled projectiles, and this is *as yet* almost the sole *practical* application. The instance, in its very singularity, forcibly impresses on the mind the inextensibility of the principle.

In this case, the motion to be controlled is as evanescent as the controlling rotation; and for *transient uses* there may be found other applications.

An ingenious one is that described in the *Revue Maritime et Coloniale*, Vol. xxxii., 1872, of the use of a gyroscopic instrument to measure the angle between the consecutive "courses" of a ship (under sail), after tacking, thus detecting (and eliminating) errors of compass due to local attraction.

PUDDLING, WROUGHT IRON, AND FUEL SAVING.

From "Iron."

It has been ascertained by actual inquiry that there are not less than eight thousand puddling furnaces in work throughout this country at this moment. The collateral branches of forging and fashioning wrought iron involve the existence of nearly double this number of furnaces. Fifteen tons of coal per week is about a fair estimate of the average consumption for each furnace. Thus, allowing a margin for stoppages for repairs, and for other sources of idleness, it will be found that in the furtherance of these great branches of our national industry, nearly ten millions of tons of coals are annually used.

A glance at these simple but comprehensive and reliable statistics will at once demonstrate the magnitude of the interests—monetary and industrial—involved in the important section of work to which they refer. Further consideration cannot fail to suggest, also, the desirability of lessening by every available means the enormous amount of fuel consumed. Metallurgists, chemists, and engineers have, indeed, devoted during the last few years very much of enlightened attention and assiduous labor to the question of economizing fuel generally, and their exertions have been crowned with a certain measure of success. Still it is a fact, that so far as puddling furnaces and others connected with the manufacture of wrought iron are concerned, they remain pretty much as they were forty or fifty years ago. As a rule, under existing circumstances, the amount of heat taken up by a charge of iron constitutes but a small portion of the whole heat generated by the furnace. The remainder passes off into the atmosphere. It is true that the escaping products of combustion are in some cases passed through boilers, thus leaving behind them a few units of heat for the generation of steam; but in the main, those products are wasted on the desert air without check of any kind.

Efforts have been made of late—and notably by Dr. Siemens and Mr. Crampton—to remedy this unsatisfactory state of things. To the first-named gentleman must be awarded the credit of being, as it were, the pioneer of furnace economy. He has taught and illustrated the value of regenerating, and that very high temperatures are possible, practicable, and economical. Yet the regenerative gas furnace has not made headway amongst iron-masters. It has met with the most faint praise or encouragement at their hands, and is apparently not destined—however ingenious and effective—to supersede, largely, the old reverberatory furnace.

The coal-dust system of Mr. Crampton, for raising high temperatures, economizing fuel, and, at the same time, minimizing the evil of oxidation in rotary puddling furnaces, has been for some time under process of experimentation at Woolwich Arsenal. A certain amount of success has been at present attained, and there is reason to expect more advantage in the future. Mr. Crampton's mode of injecting the fuel into the furnace, and thus promoting combustion in the immediate region of the metal, without the aid of fixtures or fire-grates, allows of the absolute closing of one end of the revolving barrel, while a stream of water by means of a double-way pipe, placed in line with the axis of the latter, is made to circulate throughout every portion of the external surface of the furnace. Thus a nearly perfect equilibrium of temperature through the machine is maintained during the process of puddling. This avoidance of the proximity of great heat to the mechanism for rotating the furnace which Mr. Crampton has effected, and which evil has been the bane of all other contrivances for mechanical puddling, is undoubtedly a valuable point gained. The violent and constant alternations of expansion and contraction, which have torn other apparatus for similar purposes to pieces, cannot take place in the Crampton furnace. Possibly, therefore, the "coal-dust system" may eventuate in the confirmation of rotary puddling as a permanent institution.

It is highly to the credit of the authorities of the Royal Arsenal at Woolwich that they are giving every possible attention to the momentous question of making good iron, and economizing fuel in the process. For many months past experiments have been conducted at that place with these laudable objects in view, and the results are certain to be of infinite value. One of the principal aims of those who have so zealously been working at Woolwich has been to prevent oxidation going on while the metal was under the influence of extremely high temperatures. This, it will be manifest, is a thing of vital consequence, for vain would be the economization of fuel if it were attended by a corresponding loss of metal. At present the best results effected by ordinary puddling furnaces prove that, on every ton of iron puddled, 10 per cent. must be charged for loss by oxidation, and this before it reaches the condition of bars. Now, as the annual make of wrought iron in Great Britain is, in round numbers, three and a-half millions of tons, it is clear that three hundred and fifty thousand tons of metal are yearly wasted, or returned to the normal state of an oxide. Here, then, there is ample room and verge enough for improvement. Oxidation, indeed, means something more than mere waste. In puddling furnaces, where the "cutting" action, under high temperatures, prevails, the iron is not only burnt, but permeated with cinder, and thus rendered bad.

Regarded, therefore, from whatever point of view it may, the prevention—or, at all events, the reduction of oxidation to the most extreme degree possible—is a point to be striven for unceasingly. During the attempts made at the arsenal to accomplish the desideratum, many interesting and peculiar phenomena were observed and recorded. They, however, need not be referred to further in this place. We wish rather to attract the attention of our readers to realize facts and substantial results. These facts and results cannot fail, as it is believed, to gain consideration from all who are concerned, directly or indirectly, in the vast iron industries of this and other countries. In the Royal Gun Factories department at Woolwich very much of the work to which we refer has been carried on, and is now in full operation. A grate furnace of the old style has been modified and utilized for the improved duty it was expected to perform.

In this furnace a new chamber was added at the rear of the existing fire-chamber. This arrangement compelled the fire bars to occupy a position in the middle, instead of being at the end of the furnace. The additional chamber is really formed as an upcast for the escaping products of combustion, which are conveyed into it from the opposite end of the furnace, and by means of a subterranean flue. In the upcast chamber is placed a conical retort, supported in a central position on a brick pillar, and surrounded by an open space through which the gases freely circulate. The retort, which is 10 feet in height, is of cast iron, and on its upper extremity rests a hopper, by aid of which the retort may be charged at will. A damper prevents the access of air or the escape of gas. The retort is provided with what may be termed two necks, one leading into the combustion chamber, through which the fuel is passed on to the fire-bars, and the other, on the opposite side, opening to the end, through which stoking irons or a mechanical apparatus can be applied for forcing the fuel, when needful, on to the fire-bars. The mode of lighting the furnace is to place wood on the grate-bars and kindle the fire in the ordinary way. Then the generated gases passing off find their way into the vicinity of the retort, which latter, by the time the furnace is fit for charging, will be found to have attained to very nearly a red heat.

When this is really so, the retort is charged with fuel and allowed to remain for some two or three hours. Then the stoking commences at the lower end of the retort, and the incandescent material —originally coal, but now converted into coke—finds its way gradually on to the fire-bars. The law of gravity brings down more and more of the fuel, and fresh supplies from the hopper feed the retort at its upper end or mouth. Thus the fuel in the retort is deprived of its gaseous elements, and coked by the agencies which in other cases would pass off idly through the chimney stalk—namely, the waste products of the furnace. About 25 per cent. of the fuel reaches the gaseous stage at a comparatively low temperature, namely 1,000° Fahr. The hydrogen and hydrocarbons, which in the charging of raw fuel are either imperfectly consumed from want of air and heat or mix their equivalents at the wrong place to be serviceable, namely, in the flue or the stack, are here absolutely utilized in their entirety.

The main purpose of the retort is really to separate the distinct properties of the fuel from each other, and then admit the resulting elements into the furnace under the most advantageous circumstances. Then the coke, first heated to redness, enters the fire in a condition to promote and support combustion, and so not a particle of the fuel, gaseous or solid, can possibly be wasted. Here, then, we see the saving of fuel exemplified in the most striking and complete manner, and in strict accordance both with scientific principles and natural laws.

While awaiting further and official information as to quantity of product and other details, we summarize for our readers the report we have received of what has been effected in the arsenal during the past few months with furnaces on what may be denominated the "retort" plan, as compared with the results of common practice outside that establishment.

During a period of ten weeks of continuous night and day work, the single-retort furnace at Woolwich produced of puddled iron 1 ton for every 13 cwt. of coal used. In the ordinary single puddling furnace, as used out of doors, the consumption is at the rate of 24 cwt. of coal per ton. This exhibits a saving of 45 per cent. of fuel in favor of the arsenal. Again, a reheating furnace working at the latter place for six months gave results, comparing with the common furnace, in the proportion of 4½ cwt. to 8 cwt. of coal per ton of iron, or a saving of 43 per cent. The double puddling furnace, on the retort principle, showed an advantage of 42 per cent. over the common furnace of a like kind.

As a rule, the waste in a common puddling furnace, even with the best of fettling, may be taken at 5 per cent. for a single furnace, and 10 per cent. for a double furnace, the larger capacity being conducive to oxidation, owing to the greater exposure of the "heat" to the influx of air from the working holes in balling up.

The waste in the single-retort puddling furnace has been uniformly found to be less than 2½ per cent. of iron, and in the double retort furnace it has proved to be below 5 per cent., while the fettling used in the single furnace was 6 per cent. against 8 per cent. and in the double 4 per cent. against 6 per cent.

This, with coal at 10*s.* per ton, and fettling at 30*s.*, would effect a saving in each class of furnace of from 10*s.* to 12*s.* per ton of puddled bar on the materials employed in producing it. The saving, nevertheless, does not end here. The retort furnaces themselves, from their peculiar construction, the more perfect combustion of the gases within them, their freedom from fluctuations of temperature, as well as from other minor causes, are far more durable than those constructed on the ordinary plan.

Another great point to be gained by and by, as it is expected, will be further economy resulting from the heating of the blast to a greater extent than at present. The Woolwich experiments have not hitherto heated it to above 300° Fahr., yet this has been sufficient to make manifest the economy of the practice. It is also intended, if found practicable, to introduce mechanical puddling. Thus heated air, preheated fuel, larger capacity, and labor-saving arrangements, will all be concentrated and combined, so as to ensure a yet greater economy of fuel and the production of better iron. Then, by adopting the continuous working on the three-shift system in addition, the Woolwich authorities are sanguine of being able to produce fifty tons of iron puddled per week, with possibly 8 cwt. of coal and 2 cwt. of fettling per ton.

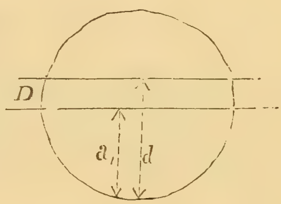
POSITION OF THE NEUTRAL AXIS IN A BENT BEAM.

BY PROF. DE FOLSON WOOD.

Written for VAN NOSTRAND'S MAGAZINE.

THE position of the neutral axis in a beam which is subjected to flexure is an important element in determining the strength of the beam. Theory shows that when the beam is perfectly elastic, and the bending forces are normal to the axis, and the material is not strained beyond the elastic limit, that the neutral axis passes through the centre of gravity of the transverse sections. Experiments have confirmed the theory in this regard. But after the limit of elasticity is passed, and the ultimate strength is approached, theory fails to indicate its true position. The experiments of Barlow and others long since showed that the theory of flexure does not apply to rupture. That is, the hypotheses—that the neutral axis is at the centre of the transverse sections, and that the strains are directly proportional to the distance of the elements from the the neutral axis—when applied to the strength of beams, do not give correct results. Barlow became satisfied from his experiments that the neutral axis remained at the centre of the beam, and endeavored to explain the discrepancy by assuming that there was another force, which he called "resistance to flexure," or longitudinal shearing. He assumed that the longitudinal shearing is evenly distributed over the transverse section; but we know that is is greatest at the neutral axis, and is nearly nought at the upper and lower surfaces. The longitudinal and transverse shearing at any point in a beam are the same. When the axis is bent into the arc of a circle, as it may be by the action of a couple, there is no transverse shearing, and hence no longitudinal shearing. Barlow's theory does not recognize this condition.

The neutral axis must move from the centre as the ultimate strength is reached. Assuming that the resistance varies directly as the distance of the elements from the axis, and we may easily find *the position of the axis for minimum strength.*



Let I_0 be the moment of inertia of the section when the axis passes through the centre;

I = the moment of the same surface about an axis parallel to the former;

D = the distance between the parallel axis;

A = the area of the section;

a_1 = the ordinate of the fibre most remote from the axis which passes through the centre;

d_1 = the corresponding distance from the parallel axis;

Then $d_1 = D + a_1$, and the well-known formula for the strength of a beam becomes

$$R\frac{I}{d_1} = R\frac{I_0 + A D^2}{a_1 + D},$$

which, by well-known rules, is a minimum for

$$D = \left[-1 \pm \sqrt{1 + \frac{I_0}{Aa_1^2}}\right] a_1$$

One of the roots is positive, and less than a_1, and the other is negative, and exceeds a_1, but both give an algebraic minimum.

For a rectangle, in which b is the breadth, and d the depth, we have

$$A = b\,d,$$

$$I_0 = \tfrac{1}{12}\,b d^3, \text{ and}$$

$$a_1 = \tfrac{1}{2}\,d$$

$$\therefore \quad D = 0.07732\,d \text{ or } -2.07732\,d$$

$$\therefore \quad R\frac{I}{d_1} = \frac{I_0 + A\,D^2}{a_1 + D} = 0.1547\,b\,d^2$$

If the axis passes through the centre, we have the well known result $\frac{1}{6}\,R\,b\,d^2 = 0.1666\,R\,bd^2$; hence the former is only 0.927 of the latter.

If the beam is circular, we have

$$D = 0.11807\,r$$

$$\therefore \quad R\frac{I}{d_1} = 0.7415\,r^3$$

which is 0.944 of the value when the axis is at the centre.

As there is nothing to determine on which side of the centre the new axis should be located, it may so happen that d_1 will equal $a_1 - D$; in which case we have a minimum for

$$D = \left[1 \mp \sqrt{1 + \frac{I_0}{A\,a_1^2}}\right] a_1,$$

which simply reverses the sign of the preceding value of D.

The result is peculiar, but does not, in any way that I now perceive, explain the discrepancy which exists between the theory commonly used and the results of experiment. It does not, as already stated, determine on which side of the centre the new axis shall be placed; neither does it take into account the character of the material. The tenacity of cast iron is say 16,000 pounds per square inch, while its crushing resistance is nearly six times that amount, or say 96,000 pounds; but the modulus of rupture is say 35,000 pounds. The tenacity of ash is about 17,000 pounds per square inch; its crushing resistance is about 9,000 pounds; and its modulus of resistance to rupture is about 12,000 pounds. There is no definite relation between these values, and hence we are unable to determine the modulus of rupture from the values of the tenacity or crushing resistance. It is determined only by experiment on the hypothesis that the axis remains at the centre.

The law of internal strains is so complex, and the position of the neutral axis so indeterminate, in a condition bordering upon rupture, that no satisfactory theory has been established for the ultimate strength of a beam. This, however, for *practical* purposes, is not to be regretted, since the load should not strain the material beyond the elastic limit.

Incombustible Wood—Experiments at Birkenhead.—Experiments were recently made at the Chain Testing Works, Birkenhead, with a plan, which has been patented, of rendering wood incombustible, and impervious to atmospheric influences. The patent is the property of Mr. C. Jarvis, of Priory, Tunbridge, Surrey, who superintended the experiments. Mr. Jarvis's process is by immersing timber in a solution of tunsgate of soda.

Samples of wood which had been immersed in the solution were subjected to several tests. One of them was to place a piece ½ in. thick in the flame of a gaslight and keep it there for thirty-five minutes. When taken out it was found to be only slightly charred to the extent of one-sixth part of it, and to have no flame upon it. About forty or fifty pieces of the prepared wood were soaked in petroleum, and then set fire to, when it was found that as soon as the petroleum had burned itself out the flame died away, and the wood was scarcely injured at all. Dr. Brown remarked that if the landing-stage had been built of wood prepared according to this patent, the recent conflagration could never have occurred. Dr. Brown subjected a piece of prepared wood to the action of oxygen gas, which was found to have very little effect upon it, whereas a piece of common wood was completely destroyed in a short time. A still more crucial test than all was tried with a piece of ordinary brown paper, which had been soaked in the solution. Mr. Jarvis wrapped up in this paper about 1 lb. of gunpowder, which he then placed in a barrel full of shavings. On a light being applied, the shavings blazed up, and were rapidly consumed, but the paper resisted the action of the flames, and the gunpowder remained intact. The result of the experiments was deemed satisfactory.

PERMANENT WAY.

From "The Engineer."

The correspondence on permanent way now proceeding in our columns is by no means devoid of interest. It raises questions which, from time to time allowed to sleep, still come up at varying intervals for discussion. It will be seen that the main argument of our correspondents is that rail joints constitute exceptionally weak places in our iron roads. The fact has been commented on for at least fifty years; and since the introduction of wrought iron rails—first used, we believe, on anything like an extensive scale, about 1823—hundreds of inventions—we do not exaggerate—have been produced to get over the difficulty. The problem is still unsolved, and it is apparently as impossible now as it has ever been to produce a system of permanent way which shall be as strong at the joints in the rails as it is elsewhere. Are we to assume, then, that the problem is insoluble? that, in short, it is simply impossible to devise a system of permanent way which shall be as strong in one place as it is anywhere else? We are slow to give an answer in the affirmative. On the contrary, we venture to think that the required system of joint may yet be devised; but it will certainly not be devised by any one who has not a most intimate acquaintance with the nature of the obstacles which he proposes to overcome. The most obvious way out of this difficulty is to scheme a system of fishing or otherwise supporting rails at joints in such a way that the joints can no longer be pointed out as localities of maximum deflection. Another method of arriving at the same end consists in so supporting the rails at the joints by the interposition of some structural element between them and the ballast that deflection will be reduced to an extremely low limit. The third arrangement is embodied in a system of construction which is intended to eliminate joints altogether. It will not be uninstructive to glance at the results which have been obtained in practice from the working of all three systems.

The most obvious, the most crude, the most popular and convenient, and possibly the least expensive device that can be included under the first division of our subject is the well known fish joint. In a way fish joints answer their purpose so well that they are universally adopted on cross-sleeper lines. If rails were very deep, and square under the heads, the fish joint would leave little to be desired. As it is found in practice, with a depth in the fish plates of about 2¼ in., and with anything rather than a square groove for the fish plate to lie in, its operation is very far from perfect, and it is well known that the best ordinary fished joint has less than one-half the strength or power of resisting deflection of the rail proper. But this is not the worst of the fish joint. If it were, then by putting the sleeper under the joint some advantage would be gained; but this plan has been tried, and without in any way improving the road. Deflection might, to a certain extent, be diminished by the use of joint sleepers, but they would not cure that disagreeable thumping with which we are all perfectly familiar—the audible manifestation of the concussion to which rolling stock is subjected. When a heavily loaded wheel is caused to run along a rail, it will be found that the rail proper continually deflects under the insistant strain, and this deflection is continually transmitted onward in advance of the wheel, the rail assuming a curve in a vertical plane, of greater or less length. When the wheel approaches a joint, however, the curve is rudely broken; the fish plates are unable to transmit the wave of deflection forward in advance of the wheel, and the result is that the rail on which the wheel is not stands a little higher than the end of the rail on which it is. The wheel encounters the higher end of the opposing rail with a certain amount of concussion. The end of the rail is by degrees hammered into fibres, and a jerk is given to the wheel and springs quite perceptible in a first-class carriage, and severely felt in heavily-loaded goods wagons, which always have bad and stiff springs. The defect in the fish joint—assuming it to be in perfect condition—is that it lacks the power to transmit the wave of deflection from one rail to the next. Is it possible to overcome this objection? Two primary causes operate to bring about the deflection of the fish joint. The first is lack of vertical stiffness in the joint itself; the second is want of stiffness in the mode of attaching the fish plates to the rail. Now, the first objection can be overcome, because we may easily give any amount of vertical depth we think proper to a pair of fish plates by carrying them down below the rail. This device has been patented over and over again, and is now being adopted in a modified form by Mr. Tomlinson, on the extension of the Metropolitan Railway from Mooregate street to Bishopgate street. No doubt some advantage is thus obtained, but it is not great. We have still to screw the fish plates to the rails by four bolts, and it is simply impossible by any system of bolts to so secure the fish plates to the rails that the former will not work on the latter under the tread of a heavy engine. Sufficient surface is not and cannot be provided. It may be shown that a certain depth of fish plate exists, the stiffness of plate proper to which will just balance the resisting power of the bolts, and of the grooves in which the plates lie, and that if the depth be exceeded nothing whatever is gained in return for the increased cost; and it is probable that this limit is very nearly reached with the ordinary $2\frac{1}{4}$ in. or $2\frac{1}{2}$ in. fish plate. Indeed, a little reflection will show that if instead of an ordinary pair of fish plates we used a girder 18 in. long and 18 ft. deep, the joint would still constitute a weak place, because the rails, from the way in which they must of necessity be united to the fishing girder, would be unable to avail themselves of its stiffness, although that would be infinite as compared with even the solid section of the rail. It follows that no augmentation of depth in a fish plate, unless it is accompanied by some improved method of securing the plates to the rails, can do much good in the only way required, that is to say, in permitting the requisite transmission of the wave of deflection from one rail to that next succeeding it. Inventors have been alive to this fact, and various devices have been employed to supplant fish bolts; but we may state here, for the benefit of any of our readers who may feel disposed to give their brains a little exercise over this problem, that no device which consists in clipping the rail or its lower table tightly has been found to answer. In all cases the rails work loose in clipping fishes, and we have no reason to think that the problem can ever be solved in this way. In one word, our conviction is that no system of fish plates alone can be devised which will permanently fulfil the required object. The problem to be solved consists not in devising a good fish plate, but in devising a satisfactory method of securing fish plates to rails, so as to become continuous with the bars to which they are fixed.

If we turn now to the second device, which consists in supporting the rails from below without the aid of fishes, we shall find that in practice the results have been no less unsatisfactory. One example of this system may be found on the great Southern and Western Railway of Ireland. This line was laid with ∩ rails of excessive weight—something like 90 lbs. to the yard—and on cross sleepers, and of course without chairs. The joints were supported on sleepers, or rather slabs of timber, frequently sawn out of beech, elm, or ash butts, and as much as 2 ft. wide. The theory was that these great sleepers would prevent deflection in the ends of the rails, and therefore that the presence of joints would hardly be felt. But the designer of this road—which we select simply as a type—forgot all about the wave of deflection, and in practice the rail was carried down under the leading wheels of the engines, and with it the slab; but the slab could not carry down the next rail, which was only spiked to it. And thus the opposing rail, drawing the spikes, stood right up off the joint sleeper, and nothing but incessant attention, and packing up and spiking down, kept the road fit for work. The unusual weight of the rails and the comparative lightness of the traffic have rendered it possible to perpetuate a vicious system in this case. It is worth notice that the stiffness of the line at the joints was nearly as great as anywhere else, although the road was, and we believe is, really very bad. That is to say, if under the tread of an engine a deflection of say $\frac{3}{16}$ in. was measured at any place in the length of a rail, then it would be found the same rail did not deflect more than $\frac{3}{16}$ in. at the end. But then the next rail did not deflect at all, but stood up $\frac{3}{16}$ in. higher than its fellow; and we need not stop to explain what the result was. In a word, each length of rail acted for itself, and at thirty miles an hour it was impossible to converse in a carriage if one of the windows were open, such was the noise. The device was ingenious and simple enough, but it would not work. Then spikes at the joints were abandoned in favor of nuts and bolts, but the bolts could never be kept tight. The nuts got loose, and the bolt heads worked into the wood; and besides, the joint sleepers or slabs, in spite of their tremendous width, "tipped" under the rails. It may be taken for granted that this system is worse than the worst that is possible with a fished road. Attempts have been made to carry out the principle in another way, joint chairs being used in which the ends of adjoining rails rested; but this scheme has totally failed, simply because the chair has always been unable to carry down the unloaded rail end with the loaded end, and the keys always worked loose. Indeed, instead of two long fish plates of iron we have under this system a short fish plate of wood in the shape of a key. One enterprising inventor went so far that the rail ends were placed in a chair the socket of which was much too large for them, and six or eight pounds of molten cast iron from a portable cupola were poured in. In this way a very good job was made. The rails were virtually welded into one, and the wave of deflection was properly transmitted; but the cost was excessive, and besides there was the fatal objection that it was all but impossible to take a worn rail out and replace it with a new one. The scheme therefore, never went beyond the experimental stage. Before going further, it will be well to explain, even more fully than we have yet done, that what is required in a rail joint is not so much that there shall be moderate deflection at a joint, as that the rail ends at both sides of the joint shall deflect equally. If a road were absolutely rigid, then all that would be needed to make a good joint would be to put a support under that joint. If the rail ends were carried in a double chair, the thing required would be obtained. But this is not what is wanted. The joint, whatever it is, must be so contrived that if one rail end descends—as it is certain to do—the other rail end shall descend equally, and no more. A practical example of the advantage which follows from securing this end, even indirectly, is supplied by Mr. Stirling's bogie express engines. These engines carry something like 15 tons on their 8 ft. driving wheels, yet they are remarkably light on the road. The four wheels of the bogie are close together, and when crossing joints they are near the rail ends, and the front wheel, so to speak, carries down the rail for the next following wheel, and consolidates the whole track for the driving wheels. We venture to think that no one has as yet devoted sufficient attention to this question of the transmission of deflection in advance of the coming wheel. All attempts have been directed to scheming rail joints to give stiffness, and that alone; whereas stiffness is a matter of secondary importance as compared with keeping the upper surfaces of the rail ends dead level with each other.

The third system of construction, which proposes the practical elimination of joints, may be dismissed very briefly, as for some cause it has never come into extended use. It was adopted—although it did not originate with the late Mr. Peter Ashcroft—on the South-Eastern Railway. The rail is compound, and consists of two angle-irons laid side by side with a steel T-piece bolted between them, the angle-irons break joint with each other and with the central table, so that virtually there is no complete joint, or, more strictly speaking, three-thirds of a joint take the place of one whole joint in a given length of road. The system works well, and gives satisfaction, but it is not free from defects, the principal being that for a considerable weight of metal the whole vertical stiffness of the road is small.

A review of all the systems that have been adopted for strengthening rail joints would fill a large volume, but it will be found by those who will do as we have done, and devote a little time to mastering the history of the subject, that promising inventions have failed because of difficulties which only extended experience in the working of railways could have suggested; and it will be seen that almost without exception designers of joints have sought for nothing but stiffness, and that they have totally omitted to secure the essential on which we have insisted—the transmission of the wave of deflection unbroken over the joint. If attention be paid to this point, we think it possible that a system of permanent way may yet be devised which will be, if not perfect, yet much superior to any now in use.

THE ENGLISH AND AMERICAN TRANSIT CAMPAIGNS COMPARED.

By RICHARD A. PROCTOR.

From the "English Mechanic."

It seems to me that a useful lesson may be learned by comparing the methods in which the two great English-speaking nations dealt with the late Transit of Venus. We English, unless stirred by emulation, are slow to move; and though we do things in a thorough way, we seldom select the most effective methods for achieving our ends. Our American cousin is less ponderous in his movements, and though to the orthodox British mind his methods may sometimes seem "rough and ready," yet he generally manages to accomplish his object, which after all is the important point. Not infrequently the ingenuity and fertility of resource of Americans enables them to go easily ahead of us—not indeed that Englishmen are wanting in these qualities, but that either we are slow to recognize them or else find their exercise not appreciated. I was repeatedly struck by this during my stay in America, not only or even chiefly in scientific matters, but in contrivances relating to the conveniences and luxuries of life. To take a few out of many examples: With an enormous country relatively thinly peopled, their system of railway travelling is altogether superior to ours; railways on our system would not pay their expenses in America, and yet notwithstanding a far higher cost per mile, our railway travelling would be simply unbearable there. With winter weather so bitter, in the greater part of the States, that by comparison the cold we thought so much of last December seems trifling, they have warm rooms and warm houses at a tenth part of the ex-expenditure of fuel by which *we* manage to roast half the body while the other is chilled by cold draughts. They have only recently (by comparison) established meteorological observatories, yet already they have morning and afternoon weather announcements, nine times out of ten correct, for the whole area of the States west of the Mississippi; while we are laboriously and at great expense publishing each day announcements of the weather of the day before, as if that could be of any real use. In scientific matters they have a quiet way of taking up and settling matters, which we in Europe have most ingeniously and elaborately failed to solve. I incline to think that this circumstance appeals rather strongly to their sense of humor; for we publish our failures rather too ostentatiously. We got the start of them, indeed, in the matter of the solar prominences, though only by departing from old usage, and giving our younger men a chance. But they showed us how to settle the question of the Corona, which we had been pottering over ineffectually; and it must never be forgotten that our Eclipse successes in 1870 and 1871 were due to their example. Prof. Young in America has gone far ahead of us, in the analysis of solar surroundings. Prof. Langley's investigation of the details of the sun's surface is far better than any yet made by European astronomers. They first photographed the moon, though some of our writers conveniently forget the Drapers, as well as later successes of Rutherferd. Every European attempt to measure the duration of the lightning flash or of the electric spark failed; but Prof. Rood (of Columbia College, New York) has not only measured the duration of the electric spark, but has actually succeeded in determining the relative duration of different portions of the flash. And this is only one instance, out of several, in which Prof. Rood has accomplished a feat of this sort—I mean the mastery of an experimental problem of exceeding delicacy. Prof. Mayer (of the Stevens Insitute, Hoboken), has successfully dealt with acoustical problems which had been practically abandoned as too difficult, by European experimenters. But these are only typical instances, selected almost at random. In passing from them let me remark that I am far from thinking that our American cousins really surpass us in scientific acumen or ingenuity, though I think they are much more fortunate in their methods and in their opportunities for exercising these qualities. It is also not unlikely that I may be disposed to speak more strongly of some instances of their power in dealing with difficult problems, because of the calm assumption of superiority observable in most European references to American science—a tone adopted in ignorance, no doubt, but which must be none the less offensive to Americans. I must hasten to say however, that Americans appear to me to be in part responsible for this fault, seeing that in some important respects they seem as it were to extend a Monroe doctrine to science.

Their action in the matter of the recent transit affords an excellent illustration of their method of dealing with scientific subjects—a method characterized by the combination of scientific exactness with readiness of resource and practical common sense.

They took up the matter much later than we did. Prof. Newcomb, in an interesting popular description of the transit in *Harper's Weekly*, speaks as follows on this point: "As far back as 1857 Prof. Airy sketched a general plan of operations for the observation of the transit, and indicated the regions of the globe in which he considered that observation should be made. In 1870, before any steps whatever were taken in America, he had advanced so far in his preparations as to have his observing huts all ready, and his instruments in progress of construction. In 1869 the Prussian Government appointed six or eight of its most eminent astronomers a commission to devise a plan of operations, and report it to the Government, with an estimate of the expenses. About the same time the Russian Government began making extensive preparations for observing the transit from a great number of stations in Siberia. Up to the end of 1870 our own authorities had done nothing at all looking to the work of taking part in these observations. But in the Naval Appropriation Bill of 1871 a clause was added appointing the Superintendent of the Naval Observatory, two professors from the same institution, the Superintendent of the Coast Survey, and the President of the National Academy of Sciences, a commission to make the necessary preparations."

Beginning so late relatively, though really in ample time, the Americans quickly formed their plan of operations. It differed in many important points from that which English astronomers had so long before adopted.

In the first place "it was determined," says Newcomb, "only to occupy stations where the whole transit would be visible." This was not merely a decision as between Halley's method and Delisle's; for the principles which guided American astronomers will apply to the transit of 1882, when Halley's method will be altogether inapplicable. The fact is, that both Delisle's method and Halley's are practically obsolete, though the principles on which they depend remain good. It is generally admitted that contact observations can be surpassed in accuracy by observations directed to the determination of the actual position of Venus on the sun's face at any moment. Accordingly it is manifest that *cœteris paribus*, the chances of success must be much greater where the whole transit can be observed, than where only the beginning or end is to be seen; and in a still higher relative degree greater than where special reliance is placed on the observation of a single contact.

Having decided to observe the whole transit, the American commission took excellent practical measures to obtain such information as might guide them in the selection of stations. We in England were satisfied by inquiries addressed to a few naval officers, who, being invited to attend a meeting of the Astronomical Society, chatted very pleasantly about the conditions of weather at Kerguelen Land, the Crozets, and in Antarctic regions; but would appear to have had no very exact information to give us. At any rate, in whatever way the matter is to be explained, they did assuredly express opinions which they afterward altogether abandoned; and thus they misled, unintentionally of course, those who had attached special value to their original statements. Prof. Newcomb thus describes the American method of dealing with the matter:

"In the northern hemisphere suitable stations were easily found, as we had the whole of China, Japan, and Northern India. But in the southern hemisphere great difficulties were encountered, owing to the want of habitable stations in the regions which are astronomically the most favorable. The South Pole would be the best station of all, if some Antarctic Kane or Hall could take a party thither. The Antarctic continent and the neighboring islands are not to be thought of, because a party can neither be landed nor subsisted there; and if they could, the weather would probably prevent any observation from being taken there." (Observe that Americans quickly found out the truth in these respects; the first statements of our authorities were the precise reverse of all this.) "The chance of having a clear sky . . . was indeed one of the most important considerations on which the choice of a station must depend, and the Commission therefore made it its business to collect information respecting the meteorology of the various possible stations from every available source, official and private. Where there was any American consul or consular agent, he was applied to through the State Department, to have meteorological observations made during the months of November and December, 1872 and 1873. A sealing ship, belonging to the firm of Williams, Haven & Co., New London, made observations at Heard's Island, in the Southern Indian Ocean." It will be seen, therefore, that the course adopted was precisely that best calculated to elicit reliable information; and whether judged by itself or by results, its superiority to the plan we pursued is manifest.

Having selected eight stations, three in the northern and five in the southern hemisphere, where the whole transit would be visible, the Americans started with a chance of success far greater than we possessed. For we had but one station in the northern hemisphere (in North India) where the whole transit could be observed; and although the whole transit could be observed at all our southern stations, yet observations of the whole transit in the south could only be properly comparable with similar observations in the north, and for these, except in the case of Roorkee, we should have to rely on the astronomers of other nations, using different methods than ours, and differently trained. Taking our English observations by themselves, and, for comparison, *inter se*—in other words, taking them in their most reliable form—they required Delislean success in Egypt *and* in New Zealand; *or* in the Sandwich Isles *and* in Kerguelen, and Rodriguez. The former combination we know has failed, and there is too much reason to fear that the second has at least partially failed; but this is not the point to be attended to. "The best laid plans of mice and men gang aft agley;" and it would be altogether unjust to condemn the English arrangements merely because of meteorological mishaps. The really important point is, that the chances of success were exceedingly small at the outset.

It is true that there are those who do not attach the same importance as I do to the comparison of observations made with similar instruments, by identical methods, and by observers similarly trained. They talk at Greenwich of "working in" Halleyan observations by Delisle's method; of comparing photographic with eye observations, and so on; and the Astronomer Royal has prepared elaborate plans for combining all the results together. It is tolerably safe, however, to assert that all such hopes are vain, and to predict that all such combinations will fail. The best way of utilizing all the results will be to consider only those obtained by the same methods, giving to each result its due weight, and *then* taking the mean in the usual manner. By any other process, differences not due to parallax will inevitably be introduced.

In fact, we find that the American astronomers recognized this at the outset. "We must remember," says Prof. Newcomb, "that in order to deduce the parallax from the observations at any two stations it is essential that the difference between observations should be due only to parallax, and that in every other respect they should be exactly the same.

Because, if there are other differences which we cannot certainly allow for, our calculations of the parallax will be wrong. It is also necessary that we compare the same kind of observations to get the parallax. To show how the chances of failure are lessened, suppose we have two stations in each hemisphere, in one of which eye-observations are made, while in the other photographs are taken. Then if the photographs in one hemisphere and the eye-observations in the other are lost by clouds or any other cause, everything will be lost, although one station in each hemisphere is successful, because the eye-observations in the one hemisphere cannot be compared with the photographs in the other."

The general plans selected by the two nations being those indicated, some difference necessarily arose as to the means of carrying them into effect. The Americans, for instance, had far less occasion than we had for testing the phenomena of contact, which, according to our arrangements, were all-important. Nevertheless, American astronomers were careful to investigate this point; in fact, they invented a more satisfactory plan than that which we borrowed from Continental astronomers. The two forms of artificial transit were not indeed unlike in principle. In the Continental model the disc of Venus was represented by a metal circle let into a glass plate, and flush with its surface, and this plate was carried behind an opening in a metal plate, the opening being bounded by two arcs which represented the sun's edge. In the American model the artificial Venus was a metal circle, one foot in diameter, and was carried in front of a white screen, two sloping edges of which represented the parts of the sun where Venus immerged and left his disc. But the model was set at a much greater distance in the American experiments than at Greenwich, and consequently, the actual extent of atmospheric undulation corresponded better with that which would affect contact occurring with the sun at any moderate elevation. The actual distance of the model at Washington amounted to 1,100 yards. I had the pleasure of studying the arrangement, and observing the phenomena with two different telescopes, on a spring morning in 1874, in company with Profs. Newcomb and Holden, who explained the details to me most fully and clearly.

In the more important question of the method for applying photography, the American and English astronomers took different courses. I set on one side, as peculiar to our plans, the use of the Janssen turning-arrangement for securing internal contacts; and speak only of the methods for photographing the progress of the transit. The English and other European astronomers set themselves the task of securing neat and well-defined sun-pictures, trusting to these pictures to indicate the true position of Venus on the sun. The Americans (and the astronomers of Lord Lindsay's party, be it noticed) set themselves the task of securing pictures which would indicate the true distance between the centres of the sun and Venus, independently of any special exactness in the definition of the limbs of the two orbs. It seems to me, viewing the matter in its mathematical aspect, that the American astronomers prove to demonstration (*using the estimates of photographic work given by De la Rue and other advocates of the European arrangement*) that the result of the best possible photographic successes by the European method cannot give the parallax with even as small a probable error as that affecting the determinations already obtained. This is a fatal flaw if real, and I can see no way of escape from Newcomb's argument. Observe in what consists the difference between the two methods. In the European plan the image formed at the focus of the object-glass is optically enlarged before it is received on the photographic plate, and consequently its proportions depend on the instrumental adjustment; in the American plan a large focal image is secured by using an object-glass of long focus (40 ft.), and the proportions of the image depend only on the focal length. Now, if the astronomer could trust to the outlines of the photographic picture of the sun and Venus as representing the exact position of the limbs, then a picture of the former plan would give its own scale, since the apparent diameter of the sun at the time of observation is very exactly known. But this is altogether hopeless in the case of photographs on glass. Reliance must be placed therefore on the accuracy of the instrumental adjustments.

But Professor Newcomb thus mercilessly takes the ground from under us. "The parallax which we seek comes out as a small difference between two long measures, namely, the difference between the centres of the sun and Venus; and each of these must be separately measured with a greater degree of real accuracy than we expect to attain in the determination of the parallax. A little calculation shows that to attain this accuracy we should know the value of the scale within the 50,000th part of its whole amount. This degree of accuracy has never been attained in the determination of any instrumental contrivance of the kind, and we might even say that it cannot be attained, because if it were found with that degree of accuracy to-day, there would be no certainty that it would not change before to-morrow under the influence of a different temperature, or a different position of the instrument."

In the American long focal plan the great difficulty to be surmounted consisted in the construction of suitable mirrors for the heliostat. Of course an ordinary telescope, 40 ft. in length, was not to be thought of, since such a telescope could not possibly be kept continually directed toward the sun by machinery. A heliostat was therefore necessary. The contrivance for working the mirror so that the sun's rays are reflected always in the same (horizontal) direction, need not here be considered. But the construction of the mirror itself was a matter of great interest and exceedingly difficult. "The slightest deviation from perfect flatness would be fatal," Newcomb points out; "for instance, if a straight-edge laid upon the glass should touch at the edges, but be the 100,000th of an inch above it at the centre, the reflector would be useless." But America is fortunate in possessing an optician of unsurpassed (I had almost said unrivalled) skill, in dealing with difficulties of this kind. "It might have seemed hopeless," proceeds Prof. Newcomb, "to seek for such a degree of accuracy, had it not been for the confidence of the commission in the mechanical genius of Alvan Clark and his sons, to whom the manufacture of the apparatus was intrusted. The mirrors were tested by showing objects through a telescope, first directly and then by reflection from the mirror. If they were seen with equally good definition in the two cases, it would show that there were no irregularities in the surface of the mirror, while if it were either concave or convex, the focus of the telescope would seem shortened or lengthened. The first test was sustained perfectly, while the circles of convexity or concavity indicated by the changes of focus of the photographic telescope *were many miles in diameter!*"

It will be seen that whether we consider their general plan, or their arrangements as to details, Americans showed themselves well advised and skilful. Instead of trusting (in the main) to a single method, they had at every one of their stations four methods available. Having ascertained the untrustworthy nature of contact observations, they took measures for determining the chord of transit by photography; and having decided on this course, they adopted a mode of photographing the sun which insured measurable pictures. As to other points in which their arrangements more nearly resembled ours, I forbear to speak. Nor, lastly, do I lay stress on the fact that results have justified their opinion as to the best methods to obtain success—for bad weather might have spoiled all. But this must be conceded—that with such weather as they actually had, plans less complete must certainly have failed.

Gauging Boiler Evaporation.—A German chemist determined by mechanical analysis the amount of water evaporated in a steam boiler. By means of a standard solution of nitrate of silver he first determines the quantity of chlorine in the feed-water, and then the quantity of chlorine in the water of the boiler at two different times several days apart. From the increased quantity of chlorides he calculates the amount of water evaporated. He commends as a suitable normal solution of silver to dissolve 23.94 grains nitrate of silver in 1,000 cubic centimetres of distilled water. Each cubic centimetre of this solution will precipitate exactly five milligrams of chlorine. To indicate the end of the reaction when all the chlorine is precipitated, he employs the neutral chromate of silver, which produces with any excess of silver solution a brighter red color.

THE EROSION OF RIFLED GUNS.

From "The Engineer."

The subject which Mr. Charles Lancaster brought last week before the Institution of Civil Engineers, viz., the rapid destruction of the interior of our heavy rifled artillery by the action of the inflamed powder, is one of great, indeed of national importance. The introduction of rifled field artillery, soon followed by the application of armor-plating to both ships and forts, rapidly led to great augmentations in the calibre of rifled guns, and in the weight of their projectiles. These in turn necessitated the abandonment of the older materials for artillery —bronze and cast iron. Then followed ringed structure, carried out in wrought iron or in steel, which, when once understood, was seen to have conferred almost limitless powers of resistance upon the guns of the future, and invited the artillerist to employ greatly increased initial velocities, great calibres, and elongated projectiles of immense mass. To meet mechanical conditions demanded for these results, ringed structure and a suitable choice of steel and iron were and are sufficient. But the magnitude of rifled guns has continued to increase, and is still increasing. Seven-inch guns have been followed by others of more than double the calibre, and the not long since wonderful 35-ton gun with its quarter ton projectile is likely ere long to be forgotten before successors of double or quadruple that weight. But long before these latter dimensions had been reached the artillerist was faced by a new difficulty, for iron and steel, with all their magnificent powers of mechanical resistance, presented greatly changed chemical relations to the erosive action of the intensely heated gases of the ignited powder, and in this respect soon proved less durable than bronze, at least if not than well chosen cast iron. The rifled shot in our system lies upon the lower side of the chase in advance of the powder cartridge, so that the greater proportion of the windage is accumulated about the upper half of the bore, between the shot and the chase. When the charge is fired the intensely heated gases act at once chemically and mechanically upon all parts of the seat of the charge, but with greatest and most destructive effect upon the upper segment of the chase, and for a length of about twice that of the projectile, where before the latter has acquired its full velocity these inflamed gases are swept with enormous velocity through the area of windage. The effect is to furrow and convert into an irregular rugose surface of alternate lumps and cavities, often reaching nearly half an inch in depth, the previously smoothly bored surface of this part of the chase, engendering many difficulties which we need not stop to detail, and soon rendering the gun unserviceable, if not unsafe. This was found to be the case, even when the 9-in. gun was the largest in our service, at which period two eminent metallurgists were invited to confer with the authorities at Woolwich as to the evil which had even then reached the formidable point as to whether several hundred "A" tubes ought not to be condemned as unsafe. That investigation proved that the results of the erosive and irregular removal of material from the interior of the chase were attended with a far more formidable consequence than had been anticipated.

When such erosion had taken place largely it was observed that fine longitudinal lines could be seen traversing the chases. They were supposed to be merely superficial, to be mere "firemarks" or other such indefinite things. But upon splitting up some of these eroded "A" tubes longitudinally, and opening the tube out flat by a slow and steady pull upon the opposite edges, it was found that these lines were in fact the lips of longitudinal fractures of various depths, some as much as half an inch. Every increase in the calibre necessarily demanding corresponding increase in the charge and weight of the projectile, increases the evil effect in a rapidly expanding ratio; for, apart from all other considerations, which space here forbids us to enter upon, the temperature of the ignited gas at the moment of explosion increases enormously with the size of the gun, the cooling agency of the metal of the gun being about in the ratio of its calibre, while the temperature of the ignited gas is roughly proportionate to the square of that dimension, so that in the very large charges of 80 lbs. or 90 lbs. the temperature of the interior of the gun is for a brief instant not far short of that theoretically deducible from the energy developed by the powder, scarcely any of it being dissipated in the form of heat passed into the metal of the gun. At this exalted temperature the products of the exploded powder, or some of them, act with intense chemical energy upon the iron or steel of the gun. Not only is the combined carbon deflagrated and removed, but the metal itself, which forms new compounds under the joint action of sulphur, nitrogen, and the potassic elements of the powder, and probably other chemical compounds with the iron tending to break up its continuity, are produced, which remain yet for the chemist to investigate fully. The particles of the material of the chase thus dissipated are swept along through the windage space at an enormous velocity and still intense temperature, and so the mechanical sweep adds severity to the chemical and mechanical action commenced further back.

Various attempts have been made in Russia, Germany, and England to meet this evil by means of different forms of gas rings applied in rear of the shot; but we doubt that any form of gas ring can do more than mitigate the evil—and scarcely even that when the gun shall have become rough by erosion. What Mr. Lancaster proposes is the application not merely of a gas ring in rear of the shot, but also certain arrangements in advance of the shot, by which not only is all windage past the thus enveloped projectile stopped after it has started into motion, but at the same instant the true centring of the projectile is secured; for with a gas ring in the rear only of the shot, the latter, though centred at the rear, lies obliquely in the gun, its ogival front resting on the bottom of the chase eccentrically, and the shot thus commencing its flight with more or less *ballotage*, to the injury of the gun and of accuracy of aim. This proposal seems to deserve a full and patient trial—one not always accorded by our artillery authorities to any invention, however promising, and which was certainly not accorded to the system of oval-bored artillery with which Mr. Lancaster's name is associated, and which was beyond question thrown aside before any serious or sufficient attempt had been made to settle definitely whether the defects alleged as to the earliest examples—namely, those tried before Sebastopol—were inherent in the system, or might have been removable by the patient experimental investigations which have rendered the Armstrong, the Krupp, and the Woolwich systems practicable, though not perfect.

REPORTS OF ENGINEERING SOCIETIES.

THE INSTITUTION OF CIVIL ENGINEERS.—A paper was read on Tuesday at this institution on "The Erosion of the Bore in Heavy Guns, and the Means for its Prevention, with Suggestions for the Improvement of Muzzle-loading Projectiles," by Mr. C. W. Lancaster, Associate Institute Civil Engineers. It was stated that one of the greatest difficulties in the practical working of the muzzle-loading guns of the British service had been the erosive action on the bore, due to the heated gases generated by the explosion of the powder finding vent on the upper side of the projectile by the windage, which was absolutely necessary to render muzzle-loading feasible. The author was of opinion that the best remedy for the evil was a simple system of rifling the bore of the gun, whereby the smoothness of the interior surface might be preserved while the rotary motion might be imparted to the projectile, and that this had been attained in the oval-bore gun and projectile.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.—At a general meeting of this Institute, Mr. J. T. Wood, the explorer of Ephesus, read an interesting paper on "The Temple of Diana," the remains of which he discovered a few years ago, in the course of excavations on the site, begun at his own cost and continued by the assistance of the British Government. Mr. Wood's exploration of the site of the temple occupied thirty-six months, and interrupted as it was by illness and other causes, extended over a period of five years. An average force of 200 men were frequently employed in the excavation, which was carried down to a depth of 22 feet. The work was discontinued by an order from the trustees of the British Museum, in March, 1874. At the conclusion of the paper, a discussion was held, in which Mr. Hyde Clarke, Mr. Penrose, Sir Charles Hartley, Mr. Cates and others joined. Regret was expressed that so interesting a work should be abandoned; and a resolution was passed referring the subject to the Institute Committee for the conservation of Ancient Monuments, with the view of memorializing the Government on the subject.

SOCIETY OF ENGINEERS.—The first ordinary meeting of the Society of Engineers for the present year was held in the society's hall, Westminster

Chambers. At the conclusion of the ordinary routine business, the retiring president, Mr. W. Macgeorge, presented the premiums of books which had been awarded to the following gentlemen for papers read during the past year—viz., to Mr. J. Phillips, for his paper on "The Forms and Constructions of Channels for the Conveyance of Sewage;" to Mr. G. G. Andre, for his paper on "The Ventilation of Coal-mines;" and to Mr. S. H. Cox, for his paper on "Recent Improvements in Tin Dressing Machinery." The premiums having been presented, Mr. Macgeorge retired from the chair, receiving a warm vote of thanks from the meeting. He then introduced to the members the president for 1875, Mr. John Henry Adams, who proceeded to deliver his inaugural address.

IRON AND STEEL NOTES.

COLLIERIES AND IRONWORKS IN CHINA.—Mr. Henderson, who has passed about thirty years in China, and who is now in England, has been commissioned by the Mandarins in charge of the arsenals of Tien-tsin and Shanghai, in pursuance of instructions from his Excellency Li-hung-chang, Viceroy of the Province of Chihli and Superintendent of Trade for the Northern Treaty Ports, to procure the necessary plant for working the collieries and iron mines, and for smelting and manufacturing iron in that province according to the most approved European methods. He has also been authorized to obtain the services of competent Europeans to direct the works. Attention has been repeatedly directed in the *Times* to the vast coal fields of China, and to the fact that steam coal, quite equal in quality to the best South Wales coal, abounds at Chaitang, in Chihli, about forty miles west of Pekin.

There is not at present a single coal mine in China worked on scientific principles; there is neither steam-engine nor pump; and the smelting of iron is conducted only in the most primitive manner.

Owing to the high prices which the Chinese are obliged to pay for foreign coal and pig iron—for the latter sometimes as much as £10 per ton—the authorities have determined to utilize some of their coal fields and deposits of ironstone, which, as well as coal, occurs in great abundance in various provinces of China, and to work them in the most systematic and advantageous manner.

The field which has been selected for commencing operations upon in the first instance is situated at P'ung C'hung, near Tre-chow, in the county of Ta-ming-fu, in the southern part of the province of Chihli, and bordering on the province of Honan. It would have been impossible to select any locality richer in coal, ironstone, and limestone, or better placed with regard to facility of access. The field is situated on a plateau bordering on and about 300 feet above the level of the great plain of Chihli, and distant about 25 miles from some small rivers, down which the produce of the mines and ironworks will be conveyed to Tien-tsin. To complete the chain of communication it is intended to construct a rail tramway from the mines to one of the rivers in question.

It is proposed, in the first instance, to meet the requirements of the national arsenals; but as soon as circumstances will permit, manufactured iron of all descriptions will be produced.

In conclusion it may be mentioned, as a notable instance of neglect to utilize national resources, that the very locality in which the authorities are about to commence mining operations is referred to in an ancient Chinese history some 2,000 years old, as being the spot where the loadstone was first discovered in China.—*Times.*

NEW MANUFACTURE OF STEEL.—A new compound metal for the manufacture of agricultural implements, &c., has just been invented and patented by Mr. J. E. Atwood. of Pittsburgh, which may be easily annealed, hammered, tempered, and fashioned into any desired shape without crumbling or breaking, as is the case with the ordinary malleable castings, and which can be tempered in water afterward, instead of being case hardened, as is necessary in the ordinary castings for this purpose. This iron possesses sufficient hardness, and is entirely free from porosity. It consists in a combination of ordinary cast or pig-iron, wrought iron, and scrap or waste iron, melted and united in the presence of a flux, which may consist of a carbonate of lime, or marble dust, or quartz rock, or any of the silicic acid compounds which contains no potash or other alkalies which will injure the iron. The combination of the ingredients forming the compound metal may be effected in various ways, either in crucibles, cupolas, furnaces, or gas or air furnaces, as may be desired. In fact, any furnace in which the proper degree of heat can be produced may be employed, and will answer the purpose. The proportion of the ingredients to be employed will vary somewhat, however, according to the means or apparatus used for effecting the combination.

When melted and combined in a crucible, cast and wrought iron are employed in equal parts; when in a cupola-furnace, in the proportion of five-eighths of cast-iron and three-eighths of wrought-iron. The scrap may be added in any desired proportion to these ingredients, as the nature of the compound may require. When the ingredients are to be combined in a gas or air furnace, three-eighths of cast-iron, four-eighths of wrought-iron, and one-eighth of scrap or old iron are used. These are all melted and combined in the presence of a flux consisting of a carbonate of lime, or marble dust, or silicon, or the silicic acid compounds containing no potash or other active alkali which would injure the iron. The scrap-iron, before being added in the mass, is melted and rendered homogeneous in any convenient manner—in a blast or cupola-furnace, for instance.

OLD BRITISH BLAST-FURNACES.—The Bowling Iron Works were founded in 1784, and the first blast-furnace was blown in there in 1788, while at the sister works of Low Moor this happened in 1791. The first furnaces had only one tuyere in the back wall, but they were soon provided with two, one in each side wall, and worked with blast of a pressure of only 2 pounds per square inch, and with nozzles $2\frac{3}{4}$ inches in diameter. It is of no mean historical interest that the Bradford district produced iron even in the time of the Romans, as is proved by the discovery of large heaps of iron slags at Bierley, about two or three miles from Bradford, which heaps enclosed coins of Roman origin.

The neighborhood of Bradford, however, was not the sole Roman iron district, as similar slags are found upon the hills of Somerset, and in very large quantities in the Forest of Dean in connection with Roman altars, dedicated to Mars, the god of iron and battle. These slags are still so rich, containing 30 to 40 per cent. of iron, that it has been deemed profitable to resmelt them, and during three centuries about twenty small charcoal blast-furnaces existed in the Forest of Dean, and were fed by these Roman slags. It is, however, unquestionable that iron was made by the ancient Britons even before the Roman conquest, as Cæsar found them to possess iron weapons and implements at his first invasion.

It is rather remarkable that Roman iron slags are always found on the tops of hills, and never in a valley, where water power could possibly have been utilized, from which it seems that the Romans did not employ bellows, but used the natural draught of the wind in so-called air bloomeries. These were hollows dug out at the top of a hill with covered channels, leading to the hillside in the direction of the prevailing wind, which would blow through them into the fire, the latter being kept up with wood or charcoal, and iron ore being introduced into the burning mass. It is evident that this process was very rough, and attended with great losses of iron, which was left in the slag. Similar air-furnaces, however, were in use for the smelting of lead in Derbyshire, as late as the seventeenth century.

As soon as bellows were introduced, about the eighth century, the smelting places became more independent, and were removed to the valleys, when so-called blast bloomeries came into use, these having built-up walls, which were gradually heightened to about 5 feet or 6 feet, with a diameter of 3 feet to 4 feet, and thus became wolf furnaces, which were employed in America and Hungary until less than 100 years ago, and are still in use in Turkey and India. These furnaces were at first rectangular, but after the sixteenth century they were made of an elliptical, and in the eighteenth of a circular section. They, however, were not in a condition to produce a fusible cast-iron, as they only could deliver lumps, "wolves," or pigs of half-malleable wrought iron.

RAILWAY NOTES.

American Car Wheels for English Railways.—A comparison of the number of accidents and injuries to passengers carried on the railways of Great Britain, with those on American roads, shows that we are conducting the travel on our railroads with greater safety to life and property than is secured abroad. The reason for this may be found probably in the more progressive spirit of American railway managers in adopting new contrivances for the safety of life and property as the best means toward the financial profit of their undertakings. The report of the Philadelphia and Reading Railroad Company, lately published, shows that nearly seven millions of passengers were carried by that company during 1874, without injury to any by fault or negligence of the company. This is an example of the very best management in railway transportation, and is, so far as we know, unequalled by the returns of any foreign company. The means by which this immunity from accident is attained are undoubtedly to be found in the adoption of the late improvements in controlling the speed of trains, as by the power brake; in lessening the danger of derailment, as by the Wharton safety switch; in an improved system of telegraphic signals, and in the substitution of iron for wooden bridges.

Another, but less frequently noted safeguard against a different character of accidents, is the general use in the United States of the cast-iron wheel with chilled tread. This article of railway carriage construction, almost unknown in Great Britain, has greatly added to the security of railway travel in this country, and deserves the attention of the English companies. The late railway accident near Oxford, on the Great Western Railway of England, by which over a hundred persons were killed or badly injured, was due to the bursting of a tire on a wheel of the type most generally employed abroad. Such an accident is now very rare with us from any cause, and almost unknown from the breakage of wheels under passenger cars. In the correspondence which always follows such a disaster abroad, one writer to the London *Times* calls the attention of that journal to the "better things" in use on American railways, among which he enumerates, first, cast-iron "tireless wheels" for railway carriages; second, a system of continuous brakes under control of the engineer, and, third, commodious and comfortable drawing room and sleeping carriages. Of the American wheel he says:

"Notwithstanding the repeated endeavors to obtain the ear of English Railway engineers of weight, with a view of their trying to get the cast-iron wheel adopted in England, I have in each case failed. As a rule, the chief objection given has been that cast-iron wheels would not suit our climate, where the changes of temperature are so frequent and sudden; and other objections, equally fallacious, have been urged. The fact is, the changes of temperature in the United States are far more frequent and far more sudden than with us.

"My object, sir, in addressing you is to urge you to exert your powerful influence to get the directors, managers, and engineers of our railways to pull the scales of prejudice from their eyes and condescend to try, with view of adopting, the cast-iron tireless wheel of the Americans, and thus, humanely speaking, save themselves and the country from such wholesale catastrophies as that of the Shipton massacre."

The export trade in car wheels has already attained respectable proportions, having been in 1873, 7,515 wheels, most of which, however, were for South American account, or were shipped to Europe generally in the form of street car wheels. In regard to the life of chilled wheels, it was stated at a late meeting of the Master Car Builders' Association, that the report of the Lake Shore Railroad showed that the wheels removed during the six months previous to April 1, 1874, had averaged 57,000 miles, the smallest average being 54,000 miles. These were 33-inch wheels, run under heavy cars at high speed. In this connection, Mr. Davenport, of the Erie Car Works, stated that he knew of iron wheels which had run 200,000 miles and were yet good. Another wheel founder stated that his company sold car wheels to the Pullman Car Company on a basis of 50,000 miles, receiving credit for any excess, and standing the loss for any that fell short. Their lowest average in mileage for the past six months was 59,000 miles. We give these details for the benefit of our English readers who may wish to insure the safety of railway travel by an important factor.—*Abstract from Iron Age.*

LOCOMOTIVE FUEL.—In commenting on some of the figures recorded in a comparative table of the consumption and cost of locomotive fuel on the leading English railways, which appeared in our issue of 24th August last, we stated that the method of computing the train mileage did not in all cases appear to give the actual mileage which trains were hauled, but was based probably on the number of hours the engines employed in hauling the trains were under steam, and we attributed the remarkably low rate of consumption noticeable on the London and South-Western line to the fact that some such system was adopted by that company in reckoning their train mileage. The following among other calculations appeared in the table referred to, and are obtained from the figures in the respective companies' report for the half-year ending December, 1871:

Company.	Quantity consumed per engine per half-year.	per train mile.
	tons.	lbs.
Glasgow and South-Western..	217	59.4
Midland....................	226	49.5
North British..............	198	45.1
South-Eastern..............	168	42 9
Great Western..............	167	40.8
Great Northern	187	40 7
Highland...................	174	40.4
Great Eastern	174	38.4
London and South-Western...	153	28.0

It is obvious that both in the average per engine and per train mile there must be certain circumstances in the nature and conditions of the work to account for these extraordinary discrepancies in the results obtained. With respect to the quantity consumed per engine per half-year the differences will not be so difficult to explain. The weight and class of engine used on the heavy lines will sufficiently explain the relatively greater consumption in their case per engine. The small average of the London and South-Western, however, is worth recording, as being due to other circumstances than those referred to. One circumstance which would tend to increase their average, but which really appears to have had the opposite effect, is that the company has a smaller stock of engines in proportion to their traffic than most other companies. It appears that in the half-year in question their stock of engines was equal to just .4 per mile of line worked, while the averages of other companies with a corresponding weight of traffic ranged as high as .7 per mile, and in no case was the average under .5. This fact is also fully borne out in the remarkably high position the London and South-Western engines occupy in a comparison of the work performed per engine. For instance, in the half-year named, the engines of the London and South-Western ran an average of 12,314 miles, while the averages on corresponding lines were 10,326 on the Great Eastern, 10,139 on the Great Northern, 9,195 on the Great Western, and 8,760 on the South-Eastern. An instance, sufficiently remarkable to be put on record here, of the large amount of work got out of the London and South-Western Company's engines recently came under our notice. An engine which left the shops, after repairs, on July 3, 1873, came in again for repairs on September 1, 1874, having also had some slight repairs in December, 1873, and in May, 1874. During the period of fourteen months this engine had run the extraordinary number of 51,686 train miles, equal to a daily average for the whole period of 120 miles, and reckoning five working days per week, the distance gone over daily could scarcely have been less than 170 miles. Examples of a less remarkable, but still very satisfactory character, are not unfrequently met with on the same line, and this, coupled with the fact of the company having so small a supply of stock, makes the average consumption of 153 tons of fuel per half-year all the more striking. Referring next to the consumption per train mile, we find the London and South-Western shows an average of only 28 lbs., against fully 45 lbs. on the eight other lines enumerated. The Great Eastern more nearly approaches to the London and South-Western than any other company in this respect, but even there the consumption is 10 lbs. per mile more than on the latter. One fact which may in some measure account for the difference is that the South-Western has a larger proportion of passenger miles than the Great Eastern.

We are now informed that these results we publish, startling as they appear, are not derived from figures other than those representing the actual train mileage, and that the method of computing the train mileage as adopted by the London and South-Western is the same as that adopted by all the other leading companies. We may also here observe, as bearing on this important subject, that in a paper read before the Institute of Civil Engineers, Mr. R. Price Williams gave it as his opinion that the London and South-Western system of working was the most economical, although it makes the charges for repairs heavier per engine but less per train mile than on other lines. It will not be without some interest to record the following results obtained on the London and South-Western, and a few other kindred lines, in the half-year just expired, ending June, 1874:

	L. & S.W.	S. E.	G. E.	G. W.	G. N.
Train miles, per engine...............	11,716	8,897	9,455	8,338	10,421
Stock of engines, per mile	.437	.690	.517	.656	.752
Earnings, per engine	3 36[illegible]	3,539	2,722	2,385	2,606
Earnings, per train mile	5s. 9d.	7s. 1½d.	5s. 9d.	5s.9d.	5s.0d.
Expenses per engine, running	356	344	327	221	302
Expenses per engine, repairs	147	119	123	114	133
Expenses per train mile, running......	7.29	9.29	8.30	6.35	6,95
Expenses per train mile, repairs.......	3.02	3.20	3.13	3.29	3 07

ENGINEERING STRUCTURES.

THE BRIDGE AT ST. LOUIS.—EFFECTS OF HEAT AND COLD ON THE GREAT STRUCTURE.—The effects of change of temperature are, at the present day, taken into account in all engineering calculations. They determine the distance between the ends of the metals on a railroad track; necessitate the use of rollers at the end of bridge trusses when the variation in their length, produced by rise or fall of temperature, is at all perceptible; require the use of expansion joints in long iron gutters and the hot air pipes of a blast furnace, and have driven civil engineers at times almost to their wits' end for "compensating" contrivances.

During the erection of Southwark Bridge across the Thames, at London, the structure was almost ruined for want of observing this natural law, the expansion of the cast-iron of the arches under the sun's rays producing a strain upon the pier, which had not entered into the engineer's calculations.

Since that time bridges have been more carefully framed with respect to thermal influences. The engineer's endeavor is to have the expansion or contraction of one part counteract the corresponding change in another part, so as to increase the stability of the whole.

It will readily be seen that the longer the span of any bridge the greater the necessity for due caution in this respect. We have here in St. Louis a bridge with arches of five hundred feet; and, to any one who has the proper means of observation, the changes in the elevation of the crown of the arches are very perceptible. In the construction of the work, calculations and allowances were made for the extreme of temperature, through a range of 140 degrees, from greatest cold in winter to the warmest day of summer, and the calculated difference in the elevation of the centre pier of the upper chord above the City Directrix at these two times was about eighteen inches.

The bridge has now long been finished. During the year the height of the centre piers of the top-chords of the arches above the City Directrix has been noted almost daily at temperatures which have ranged from 92 degrees Fahrenheit to —15 Fahrenheit, the elevations being taken with a level from the abutment of the bridge.

Now let us see how the actual facts correspond with the theoretical calculation. As the spans differ but little in length, the figures for the western span will answer every purpose.

Here they are (the "height" is that of the centre pier of the top chord above the City Directrix):

Date.	Temp. 3 P. M.	Height. in feet.
May 6, 1874	69°F.	63.548
June 29, 1874	77°F.	63.688
July 20, 1874	91°F.	63.757

Those are the higher temperatures. The cold weather showed the following state of things:

Date.	Temp.	Height in feet.
January 4, 1875	10°F.	63.241
January 9, 1875	—15°F.	63.065

The observation of January 9 last is the last one taken.

Between the figures for July 20 last and those for January 9, which two days are respectively the warmest and coldest of the year, there is a difference in temperature of 107 degrees F., and of 0.692 feet, or nearly 8 5-16 inches.

This is an effect of temperature much less than calculated, due partly to the fact of the iron work being painted white, which lessens the absorption of heat in hot weather, and increases the radiation in cold weather, and also to the protection afforded by the roof of the bridge. This latter is strikingly exemplified in the fact that the river, while frozen above and below the bridge, has yet been open under it.

At a temperature of 60 degrees the arches assume their normal curve, all members of the two chords being in equal tension. A *fall* of temperature throws the centre of the lower chord and the ends of the upper chord into tension, and the balance of the two chords into a state of compression, or, in other words, *lowers* the crown of the arch. A *rise* in temperature throws the centre of the top chord and the ends of the bottom chord into tension and compresses the remainder of the two chords, or, in common parlance, *elevates* the crown of the arch.

The position of the chords, however, is not necessarily the same on days of equal atmospheric temperature, the temperatures of the iron varying several degrees from that of the air, and being affected by the amount of moisture present in that surrounding medium.

After the experience of the past nine months the engineers and officers of the Bridge Company express themselves as entirely satisfied with the behavior of the bridge through all the climatic changes of that period, which have probably been as extensive as they ever will be in this generation or the next.—*St. Louis Globe.*

THE NEW PARIS WATERWORKS.—The great reservoirs at Montsouris for the reception of the waters of the Vannes possess great interest to the hydraulic engineer. It will be remembered that in July last a portion of the arched roof gave way. The accident has now been repaired, and the water will be let into the upper reservoir in a few days. The arches have been reconstructed as before—that is to say, two bricks thick—but the piers and supporting walls have been strengthened, and the vaulting supported in such a manner that should one or more arches fall in they will not carry the rest with them. The area of the reservoirs is 34,000 square metres, and they are two stories high, with an enormously thick wall in the middle of the whole, which divides the reservoir into four chambers, two below and two above. All the masonry of the lower chambers has been finished for a long time, but the conduits and pipes for the distribution of the water remain to be executed. The upper chamber, of which the vaultings have been reconstructed, and which has an area of 17,000 square metres, and will contain 75,000 cubic metres or tons of water, will be the first filled. The hundred arches which cover this chamber are being covered gradually with mould to the depth of 10 inches, and when this is done, and the arches show no tendency to give way, the mould will be sown with grass seed. The quantity of earth will be about two thousand cubic metres. Several hydrants are placed around the edge for the purpose of irrigating the grass. The second upper chamber is now being constructed, and is about one quarter finished. Around the reservoirs earth is now being thrown up to the height of the roof of the lower chambers, with the double view of adding support to the walls and of keeping the water within fresh. At one of the angles of the main structure rises a structure forty metres square, and with walls two metres thick. This is the receiving chamber and has been for some time in use. Its capacity is about thirty square metres by four metres deep; the bottom and sides are covered with bluish-white tiles, and the water is so pure and translucent that a motto inscribed on the tiles at the bottom is plainly visible. At the bottom of this smaller reservoir may be seen the orifice of a pipe 1.65 m. in diameter, which will carry the water to a point five metres above the level of the ground; opposite to this is another pipe of the same dimensions, which, when there is an overflow of water, will carry it to the main sewers. Just in front of this receiver are three pipes, two of them 90 centimetres in diameter, and the third somewhat less, bound together by means of a cast-iron hood, and fitted each with valves; one of these will serve to fill the upper chambers of the main reservoir, a second the lower chambers, and the third, and smallest, already supplies the highest portions of Passy with water. At the base of the recipient chamber is a telegraphic office, which is in communication with another at the reservoirs at Arcueil, with the prefecture of police, and several other public establishments, to aid in the regulation of the whole service of the city. The public is admitted to view the recipient chamber, and the purity of the water, which will shortly supply a very large proportion of the population, is a constant theme of admiration.

ORDNANCE AND NAVAL.

Improvement of Heavy Guns.—At the last meeting of the Institution of Civil Engineers, Mr. T. E. Harrison, president in the chair, the paper read was on "The Erosion of the Bore in Heavy Guns, with means for its Prevention, with Suggestions for the Improvement of Muzzle-loading Projectiles," by Mr. C. W. Lancaster. The author said:

"One of the greatest difficulties in the practical working of the muzzle-loading guns of the British service has been the rapid and injurious erosive action on the bore, due to the heated gases, generated by the ignition and explosion of the powder, finding vent on the upper side of the projectile, by the windage or difference of diameter between the calibre of the piece and the projectile, an allowance absolutely necessary to render muzzle loading feasible. The magnitude of this evil was demonstrated by the fact that the gun was disabled after a comparatively small number of rounds, and consequently had to be inverted, in order that what was previously the lowest part of the periphery of the bore should be turned uppermost, the eroded part assuming the lowest position; and subsequently, after the new portion had in its turn undergone erosion, the gun could only be rendered available for further service by being retubed with a new A-tube or steel lining. From official returns relative to the endurance of eleven 10-inch 400-pounder 18-ton guns, it appeared that after having been fired a certain number of rounds the whole of them were disabled, and required relining with new A-tubes. The average or mean effective endurance of ten of these guns was equivalent to firing 177 rounds per gun; viz., sixty-five with full charges, and 112 with battering charges. Discouraging as this state of things was, it did not represent the full extent of the evil; inasmuch as, long before the necessity arose for turning the gun, or relining it with a new steel tube, its shooting power and accuracy had been materially deteriorated, by the erosion of the bore and the concomitant wearing away of the arrises of the grooves or angles of the rifling, which were the first parts attacked by the heated gas, and by the friction of the studs in centring the projectile, and in imparting the spin of rotation on its polar axis. The nature and extent of this prejudicial effect by erosion had excited the serious consideration of the British authorities. The remedial devices and appliances hitherto proposed had assumed, in the main, two distinct forms: (1) the coating of the projectile, wholly or partially, with a soft metal envelope, such as lead, which would, when subjected to the explosive action of the powder, be squeezed out, so as to fill the bore and take the rifling; and (2) the application of certain accessories attached to, or separate from, the projectile, such as discs, gas-check rings, or wads of metal, or other suitable material. Experience had demonstrated that, with muzzle-loading, lead-coated projectiles, the powder must be limited to one-tenth the weight of the projectile. Since 1851 various devices, which were described in order of date of invention, had been tried, with more or less success, by the author, Captain Blakely, Major Bolton, Major Lyon, the Elswick Ordnance Company, Major Maitland, and again by the author, with the view of preventing the escape of gas over the projectiles, by metallic wads and other material. Trials at Shoeburyness, in 1873, gave promising results, as was subsequently testified by Sir William Armstrong, C. B., M. Inst. C. E. Still whatever appliances might be employed at the base of the projectile only, the head remained at a tangent to the axis of the bore; not thoroughly concentric as in the breech-loader, though, by the plans proposed, it was thought this difficulty might be met.

"But however efficacious these various contrivances might be, the primary and radical defects of grooved guns and studded projectiles would always remain. Accepting such ordnance as being for the present established in the British service, the author had sought to provide the means of diminishing, as far as might be practicable, their attendant defects. All reasoning on the known premises led, however, to the inference that the fundamental requirement was a simpler system of rifling the bore of the gun, whereby the smoothness and continuity of the interior surface might be preserved, while, at the same time, the necessary spin or rotary motion might be effectually imparted to the projectile. This, the author submitted, had been attained only by his own invention, known as the oval-bore gun and projectile; and his belief was that, when fully developed and fairly tried, this system would completely satisfy and fulfil all the conditions of the problem, combining a perfect gas-check and efficient centring with unsurpassed accuracy, high initial velocity, low trajectory, long range, and satisfactory powers of endurance. A careful examination and comparison of the official photographs sufficed to show that, from whatever cause, the erosive action of the powder on the oval-bore was trifling; whereas, under precisely similar conditions, it entirely disabled the ordinary Woolwich rifled gun. If, then, the principle of muzzle-loaded projectiles, which had been persistently approved by the authorities in this country, was to hold its own, and if muzzle-loading guns were to retain their place as the equals of breech-loading guns, the existing faulty and unmechanical system of rifling, with a grooved bore and studded projectiles, on which in the end the whole question turned, must be discarded in favor of a simpler and better system of rifling for gun and projectile, such as the oval-bore, a conclusion which could be established on grounds both of economy and efficiency."

TRIAL OF A NEW MONITOR.—The monitor *Sohmoës*, built by the company of the Forges et Chantiers, of the Mediterranean, for the Brazilian Government, underwent official trial at Toulon on the 5th instant. The vessel drew 3.40 metres of water, a very small draught compared with the displacement, armament, and speed of the vessel. The guns are to be supplied by Messrs. Whitworth, and the carriages by Messrs. Armstrong, but these not having arrived from England were replaced by 310 tons of ballast, placed upon the deck.

The *Sohmoës* is 73m.20 long and 17.70 in width over the armor-plates; the deck is only about om.95 above the water-line. The armor-plates, om.305 in thickness, were supplied by MM. Marrel frères, of Rive-de-Cier. Two turrets, 7m.64 exterior diameter, surmount the deck, which is formed of three layers of strong plate-iron, covered with teak. The armor-plates of the turrets vary in thickness from om.330 to om.280, and each turret is pierced for two 22-ton Wentworth guns.

Behind the fore turret is a fixed tower, for the security of the commanding officer, and over the turret is a strong bridge or false deck. When at sea the true deck will be constantly swept by the sea. The communication between the false deck and the interior of the vessel is through large rectangular shafts formed of thick iron plate, and perfectly staunch.

The turrets are turned either by hand, or by means of very simple steam apparatus, which is reported to have acted admirably. The same remarks apply to the steering apparatus, supplied by MM. Stapper de Duclos & Co., of La Capelette, who also supply the steam-crane and anchor apparatus. The anchors, which include four Martins, of $2\frac{1}{2}$ tons, can be worked either by hand or by steam. In fact, throughout the vessel, steam is called into requisition.

Two bronze screws are driven by two independent horizontal compound engines of 1,100 effective horse-power each. These engines, and also those for the twin monitor *Savary*, now under construction at Havre, were furnished by the Mazeline Company, at the last-named place.

In spite of a very fresh breeze, the speed is officially declared to have been $11\frac{1}{4}$ knots per hour, the constructors having only undertaken to give the vessel a speed of 10 knots. The monitor was delivered to the Brazil authorities on the very day twelve months that the order for her was signed.

FRANCE possessed at the close of 1873, 15,259 vessels gauging 2,077,000 tons. Twenty years previously, in 1853, the number of French merchant vessels afloat was 14,396, gauging 819,762 tons. The English merchant marine, on the 31st of December, 1873, gauged 7,294,230 tons, and in 1868 the aggregate tonnage was estimated at 7,236,916 tons. The above statistical returns would seem to intimate a considerable amount of progress in the French mercantile marine during the last 20 years, and at the same time would appear to show that there had been but a slight increase during the last five years in the English merchant service both as regards the number of vessels and their tonnage. In this case, however, the figures are deceptive, inasmuch as the apparent stationary character of the British mercantile marine is the result of the transformation of its sailing into steam fleet. The proportion of sailing vessels to steamers, according to the returns of the Board of Trade, is 1 to 7, being 4,595 steamers, against 32,230 sailing vessels. France, on the other hand, has only 1 to 35, and is already distanced by the new German Empire, which reckons 1 steamer to 23 sailing vessels.

BOOK NOTICES.

THE DRAUGHTSMAN'S HANDBOOK OF PLAN AND MAP DRAWING; INCLUDING INSTRUCTIONS FOR THE PREPARATION OF ENGINEERING, ARCHITECTURAL, AND MECHANICAL DRAWINGS. With numerous illustrations and colored examples. By GEORGE G. ANDRE, C. E., M. S. E. London. For sale by D. Van Nostrand. $6.00.

In giving to the world the book before us it is, we think, a pity that its author did not suppress the second part of its title, together with the pages to which that portion of the title refers. In other words, it would have been better to have considered the "handbook" to be devoted to plan and map drawing alone. As it is the work contains but five and a-half pages (out of a total of 150) devoted to "mechanical and architectural drawing," and necessarily a section so briefly treated cannot be of any great value to the mechanical or architectural draughtsman. This being so it would have been better to have omitted it altogether.

Of the major portion of the work, however, that devoted to plan and map drawing, we are pleased to be able to speak most favorably. Commencing with some remarks on the elements of engineering drawing in general, the author proceeds to treat clearly and in great detail of the preparation of plans and maps of all kinds. In this work Mr. Andre is evidently perfectly at home, and his book is the best handbook of map drawing we have yet met with. The plates, too (many of them colored), which illustrate this portion of the work, are admirable, and the information they afford will be of service not only to beginners but to draughtsmen of experience. In fact, the hints which these plates give, as to finishing of the details of maps and plans, are sufficient in themselves to make the book entitled to a place in all drawing offices where such work is done.

The section devoted to "mechanical and architectural drawing" is, as we have said, very brief, and quite unworthy of the rest of the book. The plates belonging to this section are but three in number, there being one good architectural plate, and two decidedly bad plates of engineering subjects. One of these shows a portion of a pair of marine engines, and it is just one of those views, incomplete and inaccurate in its details, which form such bad copies for young beginners. We can only repeat that it is a pity that Mr. Andre did not altogether omit this portion of his work. In conclusion it is only just to the publishers to mention the very good style in which the book is got up.

CERAMIC ART. A REPORT ON POTTERY, PORCELAIN, TILES, TERRA COTTA AND BRICK. Vienna Exhibition. 1873. By WILLIAM P. BLAKE, Delegate to the International Jury, &c., &c. 8vo. D. Van Nostrand. 1875. $2.00.

In this volume we have a concise but interesting notice of the very extensive display of the products of the potter's art at the Vienna Exhibition. But the descriptions range beyond what was shown there, and include observations upon the industry in the United States, its progress, and the importance of education in art, and of having good collections of typical objects in pottery of all kinds. Among the most important novelties noticed, and which are yet rare in the United States, are the beautiful enamel by Parvillee; the objects decorated in pate-sur-pate, at Minton's Art Studio, after the Sevres process, on a celadon green ground; the copies of the rare specimens of Henri-deux ware, and the cloissonee enamels. There is a very full description of the large display of tiles, a notice of the bricks and terra cotta, and a chapter upon the distribution of potters' materials. This tabular representation of the marks and monograms used upon the pottery in various countries will be found of great service to collectors.

First Lessons in Theoretical Mechanics. By the Rev. John F. Twisden, M. A., Prof. of Mathematics in the Staff College. Lond.: Longmans, Green & Co. $4.25. For sale by D. Van Nostrand.

The name of the author of these "First Lessons" is a sufficient guarantee for their excellence, and when we add that in preparing the present work, Professor Twisden has especially considered the wants of that class of readers who have but a very elementary knowledge of algebra and geometry, we have perhaps said nearly all that we need to say of the volume before us to commend it to our readers. Students who are working by themselves, however, and who have not the aid of a tutor, will be glad to know that Professor Twisden intersperses his explanations with numerical and other examples, while questions are added by which the reader can test the knowledge he has acquired. The work is well arranged, and written with great clearness, and it altogether forms a most pleasant contrast to many of the so-called "elementary" treatises now published, whose writers appear to think that their "elementary" character forms an excuse for the introduction of any number of inaccuracies. Professor Twisden's book is thoroughly sound, and we can cordially recommend it.

Graphical Method for the Analysis of Bridge Trusses; Extended to Continuous Girders and Draw Spans. By Chas. E. Greene, A. M., Prof. of Civil Engineering in the University of Michigan. D. Van Nostrand, 1875. $2.00.

In this small work of 79 pages Prof. Greene has handled in a very able manner an exceedingly difficult subject. While almost every writer upon engineering matters has tried his hand at explaining the graphic method of determining the strains in roofs and trusses, and while the market has been flooded with works, both great and small, in every sense of the word, upon bridge calculations, no person has produced a satisfactory mode of applying the graphic system to the peculiar and little understood strains in continuous girders and to pivot bridges. This Prof. Greene has done, and in a manner which cannot fail to meet the approval of engineers. The work, beginning with very elementary notions, will serve both for students and for those more advanced in the profession who need to refresh their memories upon mechanical points. The five divisions of the work show how the subject is treated: *Single Span Trusses with Horizontal Chords; Single Span Trusses with Inclined Chords; Continuous Girders of Two Spans; Continuous Girders of Many Spans;* and *Pivot Bridges.*

Without stopping to remark upon Chapters I. and II., except to say that they are exceedingly clear and go in a very short space over all the ground, we come to Chapter III., in which the author brings out the ingenious method of *area moments*, both graphically and analytically, the simplicity and beauty of which will certainly be appreciated by the student of engineering. In Chapter V., under the head of Pivot Bridges or Draw Spans, we have the best discussion of this subject which we have ever seen. A clear idea of the various strains in a draw span, when open, when shut, and when partially or fully loaded, has seldom been obtained without the use of so much of mathematics as to put it beyond the reach of any except especially intelligent students. It is upon this point that Prof. Greene has done great service to the profession. Nothing, however, but republishing the chapter would do it justice. In fine, the whole book may heartily be commended both to engineers and to engineering students.

A Manual of Metallurgy. By William Henry Greenwood, F. C. S., Associate of the Royal School of Mines, &c. Vol. I. Fuel, Iron, Steel, Tin, Antimony, Arsenic, Bismuth, and Platinum. Illustrated by 59 engravings. London and Glasgow: William Collins, Sons & Co. Price $1.50.

This is another volume of the remarkably cheap "Advanced Science Series" which has for some time past been in course of publication by Messrs. Collins, and it forms a most pleasing contrast to another volume of this series—Dr. Evers's treatise on "Steam and the Steam Engine"—which we reviewed a fortnight ago. It is by no means easy to produce a really good rudimentary treatise, on the one hand avoiding an excess of detail and on the other superficiality. Mr. Greenwood has, however, performed this task well, and his "Manual" is free from the looseness and inaccuracy which too frequently mars such books.

Mr. Greenwood commences his task by describing the physical qualities of metals, and proceeds next to treat of ores, and the modes of dressing and reducing them. Then comes a chapter on fuel, in which the author treats of wood, peat, and coal, the preparation of charcoal and coke, the theory of combustion, the calorific power of fuel, and kindred subjects. Next come six chapters devoted respectively to iron, iron ores, cast-iron, malleable iron and steel, the properties of iron and its alloy being first dealt with, and the manufacturing processes from the treatment of the raw material to the finished product being then described. Altogether nearly 150 pages are devoted to iron and steel, and in this space Mr. Greenwood has managed to touch upon all the leading processes for the reduction of iron and its conversion into steel, his description of the plan employed being assisted by numerous woodcuts. The next five chapters treat respectively of tin, antimony, arsenic, bismuth, and platinum, and in each case the properties of the metal, the nature of its ores, and the nature of the treatment they undergo are clearly described. Finally we have some addenda on various matters, and that very necessary adjunct to all technical books, an excellent index.

Altogether Mr. Greenwood has produced an excellent little manual, and we shall be pleased to see his second volume.

Economic Geology, or Geology in its Relations to the Arts and Manufactures. By David Page, L.L.D., F. G. S., &c., Prof. of Geology in Durham University College of Physical Science, Newcastle-upon-Tyne. Lond. & Edin. Wm. Blackwood & Sons. $3.75. For sale by D. Van Nostrand.

Dr. Page, who is probably already favorably known to many of our readers, by his former works on geology, has, in the volume before us, furnished us with an excellent little text-book. To a certain extent, too, Dr. Page has broken new ground, and his book is just what it professes to be—not a treatise on geology in general, but one which specially treats of those branches of the science which are useful to those engaged in the industrial arts.

Our author commences his task by explaining the aim and object of economic geology, and then proceeds to describe clearly but briefly the composition of the rocky crust of this world of ours. Next he passes on to a consideration of the connection between "geology and agriculture"—treating of soils, sub-soils, and mineral manures—and next to the valuation of lands, their surface or agricultural value, and their mineral or geological value being separately dealt with. Then come two sections on "Geology and Architecture," and these are followed by others on geology and civil engineering; geology and mine engineering; heat and light-producing materials; geology and the fictile arts; grinding, whetting, and polishing materials; refractory or fire-resisting substances; pigments, dyes, and detergents; salts and saline earths; mineral and thermal springs; mineral medicines; guns and precious stones; the metals and metallic ores; and finally a general summary.

We have given this list of the sections of Dr. Page's book, because it is really only by so doing that we can convey an idea of the comprehensive nature of its contents. It must not be considered, however, that because so many subjects are referred to that they are dealt with superficially, for this is decidedly not the case. Dr. Page possesses the happy power of condensing information without making it either superficial or uninteresting, and while his book is a perfect mine of facts, these facts are so stated as to be eminently readable. The book is accompanied by a well-executed geological map of Great Britain and Ireland, and illustrated by some excellent wood engravings, and it is altogether a volume which we can heartily recommend to our readers to add to their libraries.

MISCELLANEOUS.

A German trade circular describes two kinds of black stain for wood: (1) the ordinary black stain for different kinds of wood; (2) the black ebony stain for certain woods which approach nearest to ebony in hardness and weight. The ordinary black-wood stain is obtained by boiling together blue Brazil wood, powdered gall apples, and alum, in rain or river water, until it becomes black. This liquid is then filtered through a fine organzine, and the objects painted with a new brush before the decoction has cooled, and this repeated until the wood appears of a fine black color. It is then coated with the following liquid: a mixture of iron filings, vitriol, and vinegar is heated (without boiling), and left a few days to settle. If the wood is black enough, yet for the sake of durability, it must be coated with a solution of alum and nitric acid, mixed with a little verdigris, then a decoction of gall apples and logwood dyes are used to give it a deep black. A decoction may be made of brown Brazil wood with alum in rain water, without gall apples; the wood is left standing in it for some days in a moderately warm place, and to it merely iron filings in strong vinegar are added, and both are boiled with the wood over a gentle fire. For this purpose soft pear wood is chosen, which is preferable to all others for black staining. For the fine black ebony stain, apple, pear, and hazel wood are recommended in preference for this; especially when these kinds of wood have no projecting veins they may be successfully coated with black stain, and are then most complete imitations of the natural ebony. For this compound 14 oz. of gall apples, $3\frac{1}{2}$ oz. of rasped logwood, $1\frac{3}{4}$ oz of vitriol, and $1\frac{3}{4}$ oz. of distilled verdigris are boiled together with water in a well-glazed pot, the decoction filtered while it is warm, and the wood coated with repeated hot layers of it. For a second coating a mixture of $3\frac{1}{2}$ oz. of pure iron filings, dissolved in $\frac{3}{4}$ of a litre of strong wine vinegar, is warmed, and when cool the wood already blackened is coated two or three times with it, allowing each coat to dry between. For articles which are to be thoroughly saturated, a mixture of $1\frac{3}{4}$ oz. of sal-ammoniac, with a sufficient quantity of steel filings, is to be placed in a suitable vessel, strong vinegar poured upon it, and left for fourteen days in a gently heated oven. A strong lye is now put into a good pot, to which is added coarsely bruised gall apples and blue Brazil shavings, and exposed for the same time as the former to the gentle heat of an oven, which will then yield a good liquid. The pearwood articles are now laid in the first-named stain, boiled for a few hours, and left in for three days longer; they are then placed in the second stain, and treated as in the first. If the articles are not then thoroughly saturated, they may be once more placed in the first bath, and then in the second.—*Engineer.*

The World's Steam Power.—Dr. Engel, director of the Prussian Statistical Bureau, has endeavored to find out the amount of steam power in use in the world; but the returns for stationary steam engines include only old and partial reports for five countries, including the United States, Great Britain, and France. The number of engines in five countries, according to reports, some of which were prepared in 1860, was 121,755, and the horse-power was 2,761,880. Dr. Engel estimates that there cannot be less than 150,000 stationary engines, with from three to three-and-a-half millions of horse-power in the world. The returns with reference to locomotives and their power are much fuller, although they also are incomplete, and some of them dated four years ago. The total number of locomotives embraced in these returns is 45,467. It is estimated there are at least 50,000 locomotives, with an aggregate of ten million horse-power. The ocean steamers, according to the returns, number 5,255. The estimated horse-power of steam-engines, stationary, locomotive, and marine, is 14,400. The United States leads the world in the number of its stationary and locomotive engines, but Great Britain is credited with having more steam-vessels and more tonnage than all the rest of the world.

VAN NOSTRAND'S
ELECTIC
ENGINEERING MAGAZINE.

NO. LXXVII.—MAY, 1875.—VOL. XII.

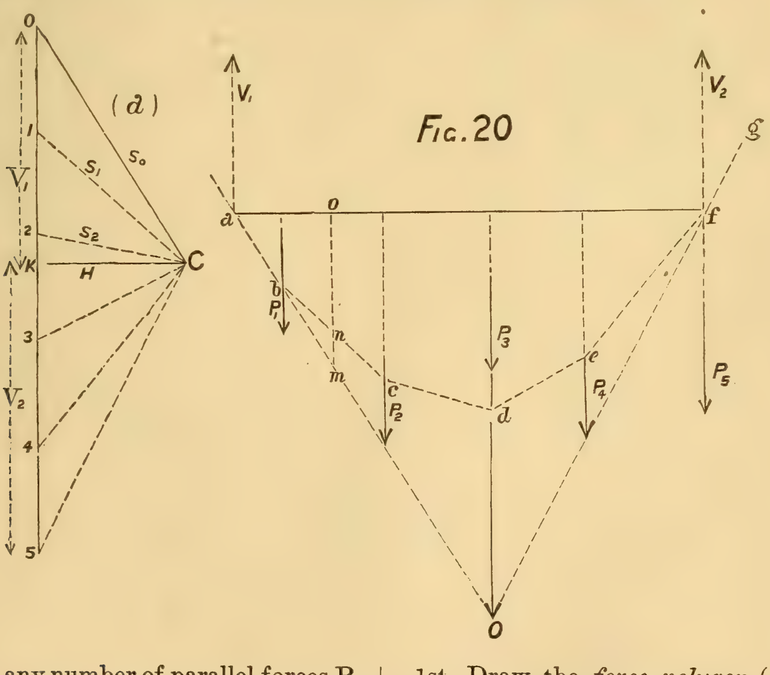
THE NEW METHOD OF "GRAPHICAL STATICS."

BY A. J. DU BOIS, C. E., PH. D.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

38. EQUILIBRIUM POLYGON.

Since the forces acting upon structures are generally due to the action of gravity, these forces may be considered as parallel and vertical, and in all practical cases therefore we have to do with a system of parallel forces.



Given any number of parallel forces $P_{1\text{-}5}$ Fig. 20; required to find the direction, intensity and position of the resultant, and the moment of rotation at any point.

1st. Draw the *force polygon* (*a*). In this case it is of course a straight line.

2d. Choose a *pole* C, and draw the lines S_0 S'_1 S'_2, etc.

3d. Draw the string or equilibrium polygon *a b c d e f*. Considering this polygon as a system of *strings*, the forces will be held in equilibrium if we join any two points, as *a* and *f*, by a strut or compression piece, and apply at *a* and *f* the upward forces V_1 and V_2.

4th. Prolong *ab* and *fg* to their intersection O. Through this point the resultant must pass. It is of course parallel and equal to the sum of the forces.

Now, if *a f* is assumed horizontal, the perpendicular H to the force line, or the "*pole distance*," divides the resultant 0 5 into the two forces V_1 and V_2.

All the forces in the equilibrium polygon, have the same horizontal projection H, in the force polygon.

Let *a f* represent a *beam* resting upon supports at *a* and *f*. We have then at once the vertical reactions V_1 and V_2 or K 0 and 5 K, which, in order to cause equilibrium, must act *upwards*.

For the moment at any point, as 0, due to V_1, we have, by Calmunn's principle, m 0 multiplied by H. The triangle formed by *ab*, *af*, and P_1, gives then the moment of rupture at any point of the beam as far as P_1. For a point 0, beyond P_1, the moment due to V_1, must be *diminished* by that due to P_1, since these forces act in opposite directions, and rotation from left to right is considered positive. We see at once from the force polygon (*a*) that P_1 is resolved into S_0 and S_1 or into *a b* and *b c*. Hence the moment at 0 due to P_1 is *m n* multiplied by H. The total moment at *o* is then $m\,o - m\,n = n\,o$, multiplied by H.

Hence we see that *the ordinates to the equilibrium polygon from the closing line a f are proportional to the total moments, while the ordinate at any point between any two adjacent sides of this polygon, prolonged, represents the moment at that point of a force acting in the vertical through the intersection of these two sides.*

[The reader should make the construction, changing the *order* in which the weights are taken, and thus satisfy himself that the order is a matter of indifference. As to the *direction* of the reactions V_1, V_2, it must be remembered that *a b* is to be *replaced* by V_1 and H, hence V_1 must be opposed to C 0, the direction obtained by following round in the force polygon the triangle 0 I C. Force and distance *scales* should also be assumed. Thus the ordinates to the equilibrium polygon scaled off say in inches, and multipled by the number of tons to one inch, and then by the "pole distance" taken to the assumed scale of distance, will give the moments of any point.]

The resultant of *any* two or more forces must pass through the intersection of the outer sides of the equilibrium polygon for those forces (art. 16). Thus, the resultant of P_1 and P_2 must pass through the intersection of *a b* and *c d*. Of V_1 and P_1, through the intersection of *a f* and *b c*; of P_1 P_2 and P_3, through intersection of *a b* and *d e*, and so on. In every case the intensity and direction of action of the resultant is given directly by simple inspection of the force polygon.

Thus from the force polygon we see that the resultants K 2 and K 3 of $V_1 P_1 P_2$ and $V_1 P_1 P_2 P_3$, act in *different* directions. Their points of application are at the intersection of *c d* and *d e* respectively with *a f*, or upon either side of *d* in the equilibrium polygon. At *d* the ordinate and hence the moment is greatest, and at this point the tangent to the polygon is parallel to *a f*. If we had a continuous succession of forces; if *a f*, for instance were continuously or uniformly loaded; the equilibrium polygon would become a *curve*, and the tangent at *d* would then coincide with the very short polygon side at that point. The points of application of the resultants of all the forces right and left of *d* are then at the intersection of this tangent with *a f*, or *at an infinite distance.*

At *d* then we have a *couple*, the resultant of which is as we have seen (art. 20), an indefinitely small force acting at an indefinitely great distance. That is, with reference to *d*, the forces acting right and left cannot be replaced by a single force.

Hence generally: at the point of maximum moment ("*cross section of rupture*"), the sum of the outer forces on either side reduces to an indefinitely small and distant force, the direction of which is reversed at this point, and the point of application of which changes from one side to the other of the equilibrium polygon.*

* *Die Graphische Statik. –Culmann, p.* 127.

The "*cross section of rupture*," then, *is that point where the sum of the forces between it and one end is equal to the reaction at that end, or where the resultant of these forces changes sign.*

The *value of the moment* at this point, is therefore *equal to the product of the reaction at one end into its distance from the point of application of the resultant of all the forces between that end and the point.*

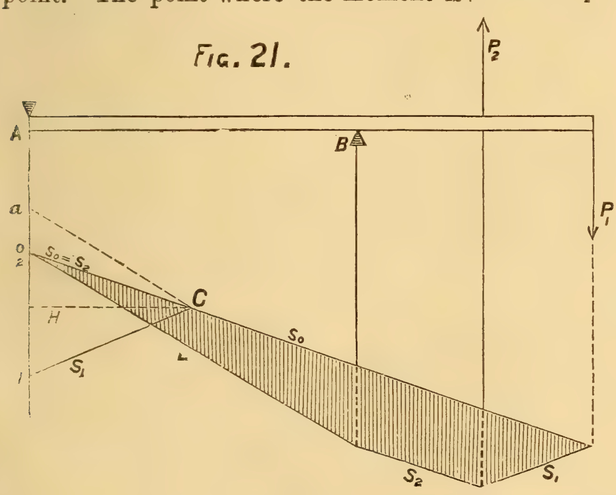
Thus for a beam uniformly loaded with w per unit of length, the reaction at each end is $\frac{wl}{2}$. From the above, the cross section of rupture is then at the middle. The point of application of the resultant of the forces acting between one end and the middle is at $\frac{l}{4}$, hence the maximum moment is $\frac{wl}{2} \times \frac{l}{4} = \frac{wl^2}{8}$.

39. BEAM WITH TWO EQUAL AND OPPOSITE FORCES BEYOND THE SUPPORTS.

The ordinates to the equilibrium polygon thus give, as it were, a *picture* or simultaneous view of the change and relative amount of the moments at any point. The point where the moment is greatest, *i.e.*, where the beam is most strained, is at once determined by simple inspection.

Let us take as an example a beam with two equal and opposite forces *beyond* the supports. Thus, Fig. 21, suppose the beam has supports at A and B, the forces being taken in the order as represented by $P_1 P_2$. We first construct the force polygon from o to 1, and 1 to 2 or o. Next choose a pole C, and draw S_0 S_1 and S_2. Draw then a parallel to S_0 till intersection with P_1, then parallel with S_1 to P_1, then parallel to S_2 or S_0 to intersection with vertical through support B, and finally draw the *closing line* L. A line through C, parallel to L, gives as before the vertical reactions. Following round the force polygon, we find at A the reaction *downwards*, since S_0 acts from C to o and is to be *replaced* by L and V_1; at B reaction *upwards*, since P_2 acts up, and following round, S_2 acts from o to C. *Both* reactions are *equal to a o*. At A then the support must be above, and at B below the beam. The shaded area gives the moments to pole distance H. Had we taken the pole in the perpendicular through o, S_0 would have been parallel with the beam itself. This is, however, a matter of indifference. The moment area may lie at *any* inclination to the beam. We also see here again the effect of a *couple* (art. 23). S_0 is simply *shifted* through a certain distance to S_2, parallel to S_0, and therefore the moment at any point between P_2 and B is *constant*. This is generally true of any couple, as we have already seen, Article 21, and may be proved analytically as follows:

Fig. 21.

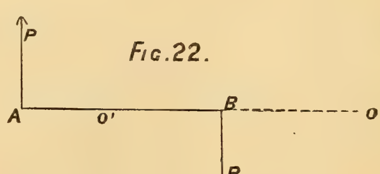


Let the distance between the forces be a=A B, Fig. 22. Then for any point o, we have $P \times (a + B\,o) - P \times B\,o = P[a + B\,o - B\,o] = P\,a$. For o' between A and B, $P \times Ao' + P \times o'B = P[Ao' + o'B] = Pa$.

So also for any point to the left, the same holds true.

Graphically the proof is as follows:

Fig. 22.



Decompose both forces into parallel components, Fig. 23. Then for any

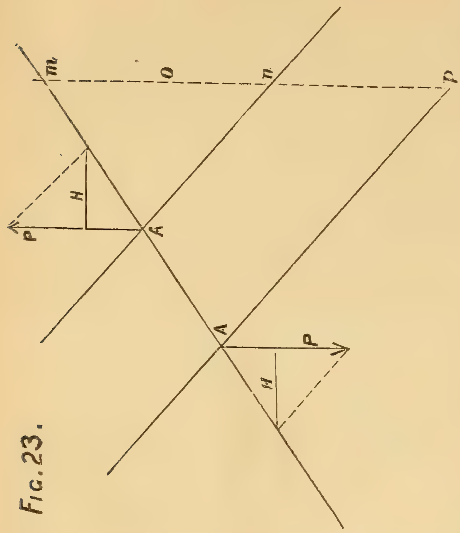


Fig. 23.

point, as o, we have the moment $M = H \times mn - H \times mp$ or $M = -H \times np$. But np is the constant ordinate between the parallel components An and Ap.

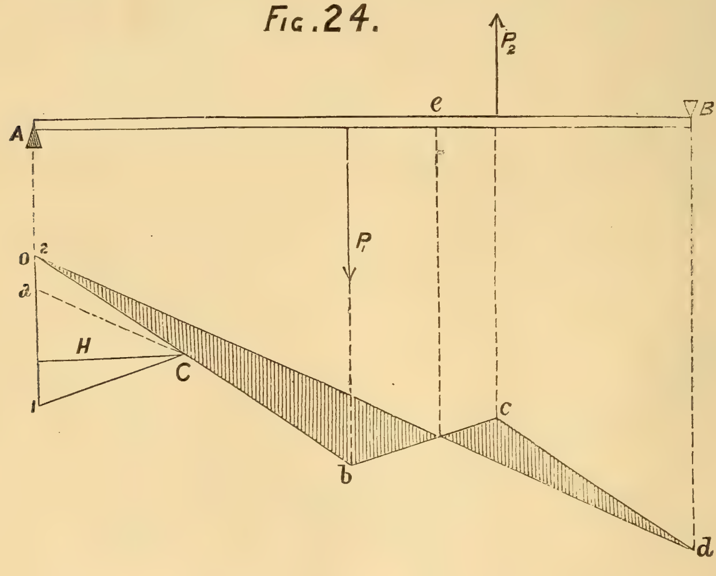
We see, therefore, by simple inspection, that the distance of P_1 and P_2 from the support B, Fig. 21, has no influence whatever upon the moment or strain in A B, provided the distance between the points of application remains the same, and that the moment at all points between P_2 and the support B is constant and a maximum. From B and P_2 the moments decrease left and right, and become zero at A and P_1.

40. BEAM WITH TWO EQUAL AND OPPOSITE FORCES BETWEEN THE TWO SUPPORTS.

Let the beam A B, Fig. 24, be acted upon by the two equal and opposite forces $P_1 P_2$.

Construct the force polygon o 1 2. Choose a pole C and draw Co C1 C2. Parallel to Co, draw the first side of the equilibrium polygon to intersection with P_1; then parallel to C 1 to P_2, then parallel to C 2 to d. Join d and o. Parallel to this draw C a in force polygon. Then $o\,a$ is the vertical reaction at A, which acts upwards, since it must with C a *replace* C o, and C o, when we follow

Fig. 24.



round from o to 1 and 1 to C, acts from C to o.

We have the same vertical reaction at B, but here, since we must follow from 1 to 2 and 2 to C, C 2 acts from 2 to C, hence the reaction at B is downward.

We see at once that at a certain point e the moment is zero. Left and right of this point the moment is positive and negative. At the point itself we have a *point of inflection*, and here, since the moment is zero, there is *no strain*. At *b* and *c* the moments are greatest; here the beam is most strained, and at these points, therefore, are the cross sections of rupture. Here again, if we had taken the pole C in the perpendicular through *a*, the closing line of the polygon *o d* would have been horizontal. It is, however, indifferent at what inclination *a d* may lie, but we may if we wish make it horizontal *now*, and then lay off from its new intersections with P_1 and P_2 along the directions of these forces, the ordinates already found at *b* and *c*, and join the points thus obtained with the ends of *o d* (*i.e.*, with its intersections with the verticals through the supports). The ordinates of the new polygon thus found will be for any point the same as before, and will also be perpendicular to the beam.

[*Note.*—Had we taken the forces precisely as above but in *reverse order*, the force line would be reversed, and we should have *o* and 2 in place of 1, and 1 in place of *o* and 2; that is, in place of C 1 we should have C *o* and C 2. Constructing then the equilibrium polygon by drawing a line parallel to new C *o* to intersection with new P_1, then parallel to new C 1 to intersection with new P_2, then parallel with new C 2 to intersection with vertical through B, and finally joining this last point with intersection of the first line drawn (C *o*) with vertical through A, we have at first sight a very different equilibrium polygon. This new polygon will consist of *two* parts. If the ordinates in one of these parts are considered positive, those in the other must be negative. The *difference* of the ordinates in these two portions for any point, will give the same result as above. This, by making the above construction, the reader can easily prove.]

41. Many other problems will readily occur, which may in a similar manner be solved. The weights may have any position, number and intensities desired; in any and every case we have only to construct with assumed pole distance the corresponding equilibrium polygon, and we obtain at once the moments at every point. By the use of convenient scales, numerical results may be obtained which may be checked by calculation, and the practical value and accuracy of the method thus demonstrated.

The above principles will be sufficient for the solution of any such problem which may arise, and we shall therefore content ourselves with the above general indication of the method of procedure, and pass on to the consideration of a few cases where the above needs slight modification, and which, from their practical importance, and the ease with which they may be treated graphically, seem worthy of special notice.

1st. Beam or Axle—Load Inclined to Axis. [Fig. 25.]*

We have here simply to draw the "closing line" A C parallel to the beam

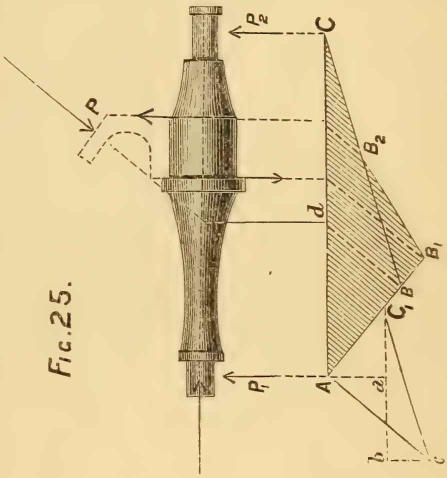


Fig. 25.

or axle. From *d* draw *d* B parallel to the forced P, then draw A B in *any* direction at pleasure, and join B C. We have thus the equilibrium polygon ABC, the ordinates to which, as *d* B, *parallel to the force* P, will give the moments, *provided we know the corresponding pole distance.*

But this can easily be found. As we have already seen, the force polygon being given, the equilibrium polygon may be easily constructed. Inversely, the equilibrium polygon being given, the force polygon may be constructed. Thus, from A draw A *c* equal and parallel to P, and then draw *c* C_1 parallel to B C. A *a* and *b c* are the vertical reactions at P_1 and P_2; *a b* is the horizontal component of the force which must be resisted at one or both of the ends; and the moments at any point are given by the

* See *Reuleaux-Der Constructeur.*

ordinates parallel to P multiplied by the perpendicular distance from C_1 to $A c$. If we suppose the force P, as in the Fig., as causing two opposite vertical forces, instead of acting directly upon the axis, we have only to prolong A B to B_1 and join $B_1 B_2$, and then the ordinates of $A B_1 B_2 C$ parallel to P or $A c$, multiplied by H (perpendicular distance from C_1 to $A c$) will give the moments.

2D. FORCE PARALLEL TO AXIS, FIG 26.

We have an example of this case in he "bayonnet slide" of the locomotive engine.

We have here two pairs of forces, the reactions V_1 and V_2 and the forces over B_1 and B_2. The points of application of these last, change of course periodically, but for any assumed position the moments are easily found. Thus draw $A B_1$ at pleasure, and C B_2 parallel to it, and join $B_1 B_2$ and A C, and we have at once the equilibrium polygon. To find the corresponding *force polygon*, suppose P_1 applied at *b*, and join *b* with the other support. Make *b c* equal to P then $c d = V_2$. Say off then $A a = c d = V_2$ and draw $a C_1$, which is the *pole distance.* Draw $C_1 e$ parallel to $B_1 B_2$. Then A *e* and *e* A are the forces acting over B_2 and B_1, and A *a* is the reaction V_1. The case is,

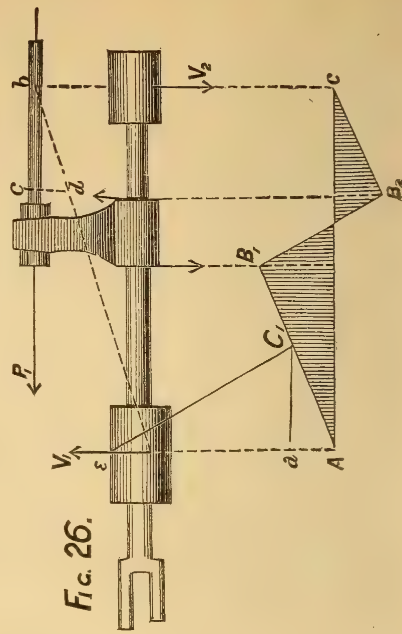


Fig. 26.

indeed, precisely similar to that in Art. 40.

[*Note.*—The moment area should properly be turned over upon A C as an axis, so that A *a* should be laid off and *e* fall *below* A. This can, however, cause no confusion.]

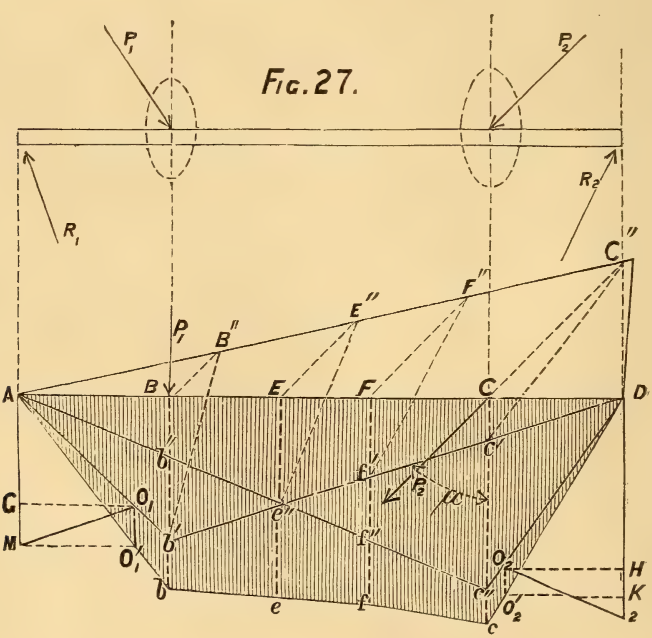


Fig. 27.

The application of the method to car axles,* crane standards, and a large number of similar practical cases in Mechanics is obvious. The formulæ for many of these cases are too complex for practical use; in some no attempt at investigation of strain is ever made, the proportions being regulated simply by "Engineering precedent" or rules of thumb. Those familiar with the analytical discussion of such cases will readily recognize the great practical advantages of the Graphical Method.

3D. BEAM OR AXLE ACTED UPON BY FORCES LYING IN DIFFERENT PLANES.

The analytical calculation in such a case is of considerable intricacy, but by the graphical method, on the contrary, the difficulty of investigation is scarcely greater than before.

Thus, let Fig. 27 represent a beam acted upon by two forces P_1 and P_2 *not in the same plane.*

First, we draw the force polygons A O_1 M and D $O_2{}^2$ for the forces P_1 and P_2, having both the *same* pole distance G O_1 $=O_2$ H, the pole O_2 being so taken that the closing lines of the corresponding polygons A b'' D and A C'' D coincide. This is easily done, as if the closing line of the second polygon for any assumed position of O_2 (O_2 H being equal to G O_1) does not coincide with A D, the ordinate at C'' can be laid off from C and A C'' D thus found in proper position, and then the pole O_2 can be located. It will evidently be at the intersection of $O_2\,O'_2$ with C'' D.

The two force polygons being thus formed, we construct the polygon A C'' D by drawing lines B B'', E E'', C C'', etc., so that their angles with the vertical shall be equal to the angle between the planes of the forces, and making them equal to the ordinates B b'', E e, F f'', etc., respectively. Join b' B'', e' E'', f' F'', c'' C'', etc., and lay off the ordinates B b, E e, F f, C c, etc., respectively equal. The ordinates to the polygon thus obtained, viz. : A $b\,e\,f\,c$ D multiplied by the *pole distance* O_1 G or O_2 H, give the moment at any point. A b and c D are straight lines, $b\,e\,f\,c$ is a curve (hyperbola). If we drop verticals through O_1 and O_2, and draw the perpendiculars O'_1 M, O'_1 K, A M is the reaction R_1, and D K the reaction R_2, both measured to the scale of the force polygon. Their

* *Reuleaux-Der Constructeur*, p. 215–222.

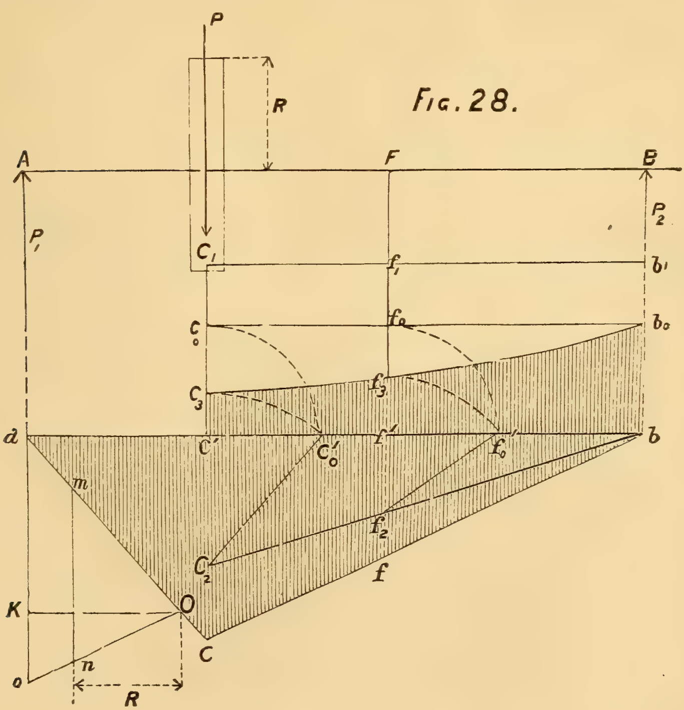


FIG. 28.

directions are found by the composition of A G and H_2 and D H and G M respectively, under the angle of the forces.

4TH. COMBINED TWISTING AND BENDING MOMENTS.

In many constructions pieces occur which are subjected at the same time to both bending and *twisting* moments. Both can be represented and given by moment areas. Thus, Fig. 28 represents an axle turning upon supports at A and B and having at C a wheel upon which the force P acts tangentially. We have then a moment of torsion $M_t = P\,R$ and reactions $P_1 = P\frac{s}{a+s}$ and $P_2 = P\frac{s}{a+s}$, s being the distance of P from B, and a of P_1 from P.

Let the bending moments be represented by the ordinates to the polygon *a c b*, then laying off *a o* equal to P and drawing *o* O parallel to *b c*, we find the *corresponding pole distance* O K, and the reactions P_1 and P_2 equal to K *a* and O K respectively.

Now, in the force polygon *s* O *a o* thus found, at a distance from O equal to R, draw a line *m n* parallel to P. This line *m n* evidently gives *for the same pole distance*, the moment of torsion P×R. Laying off $C'\,C_1 = b\,b_1 = m\,n$, we have the torsion rectangle $c_1\,b_1\,b\,c'$.

Now the combined moment of torsion M_t and bending $M_b \cdot \frac{3}{8}\,M_b + \frac{5}{8}\sqrt{M_b^2 + M_t^2}$* We make then $C'C_0$ equal to $\frac{5}{8}\,C'C_1 = \frac{5}{8}\,mn$ and CC_2 equal to $\frac{3}{8}\,CC' = M_b$, and draw $C_2 b$. Then any segment of any ordinate, as $f f_2$ is $\frac{3}{8}$ of $f f'$. Revolve now $C'\,C_0$ with C′ as a centre, round to C'_0 and join $C'_0\,C_2$. Then $C_2\,C'_0$ is equal to $\frac{5}{8}\sqrt{M_b^2 + M_t^2}$, and therefore with C_2 as centre revolving $C_2 C'_0$ to C_3, we find the point C_3, $C\,C_3$ being equal to $\frac{3}{8}\,M_b + \frac{5}{8}\sqrt{M_b^2 + M_t^2}$. In the same way we find any other point as f_3, by laying off $f'\,f'_0$ equal to $f'\,f_0$, joining f_2 and f'_0 and making $f_2 f'_3$ equal to $f_2 f'_0$. The line $C_3 f_3 b_0$ thus found is a hyperbola, and the ordinates between it and *b c* give the combined moments [for pole distance O K] at any point.

[*Note.*—We suppose the axle to turn freely at A, and the working point or resistance beyond B; hence the moments left of the wheel are given by the ordinates to *a c.*]

* *Reauleaux-Der Constructeur*, p. 52, Art. 18.

STREETS.*

BY B. H. CUNNINGHAM.

From "Engineering."

THE object of this paper is to describe the street coverings now most used, and to show their relative advantages and defects. But before we can weigh these fairly, or form reasonable opinions regarding them, we must have distinct ideas about the nature of roads in general, and we must find out what a good road really is. I shall, therefore, in the first place endeavor to make a comprehensive theory of roads, and in order to do this shall enumerate and describe the qualities which a good road ought to possess. We shall thus see what ends road-makers should aim at, and what difficulties they have to overcome. Secondly, I shall proceed to apply this general theory of roads to one particular case, viz., streets, dividing all kinds of modern streets into four great classes:

I. Macadam, and Macadam Concrete Sts.
II. Streets paved with stone setts.
III. Streets paved with wood.
IV. Streets paved with asphalt.

Thus you may see that having found out what a road is, our attention will be confined to the roads now made in this country, or in countries like it in civilization and physical features;—and further, that it will be confined to these in or near cities where the traffic is large and heavy, that is to say, to streets.

Having adopted these limits, we will not enter upon such subjects as the ancient and modern history of roads—the principles which guide their exploration—the methods of construction adopted in remote colonies and western states—or the working of our own highway

* Paper read before the Edinburgh and Leith Society.

Acts. Passing references will however be made to history, whenever it affords us useful hints, either in the way of example or warning. Finally, I must explain that this paper is no record of original observation or experiments. Still, I venture to hope that it will not be found uninteresting or useless. In the first place, the theories of some of those who have made roads well, or had them long under their charge, are stated and examined; so that, if possible, we may compile a sound and comprehensive theory of our own. Secondly, a good many facts have been collected from various scattered sources and grouped together, so that they may be easily referred to and compared. The consideration of these facts will, I hope, show the relative advantages of the four kinds of streets already mentioned. Having thus cleared and defined our ground, we may now endeavor to answer the question, What is a good road?

It is not easy to do this in a single sentence, therefore it seems best to adopt the method already indicated and enumerate the qualities which a good road ought to possess. These are:

I. *Surface Hardness.*—Wheels and horses' feet must not sink or cut into its substance. Brittle hardness might be enough to prevent this, but a road surface must have toughness. It must stand the wear caused by the rolling or grinding of the traffic, also the blows from horses' hoofs, and the jolting and concussions of vehicles.

II. *Smoothness.*—When this quality is conbined with hardness, we at once obtain five things which are of great value to all connected with roads.

1. *Minimum Wear of Surface.*—It is a euphemism to speak of a carriage rolling along a road, as the real motion is of a very different kind. Let us watch an empty cab, while being driven quickly over an ordinary granite pavement. This is certainly an extreme case, but for that reason it shows clearly the action which takes place. It can easily be seen that the cab advances by a series of small jumps, and gives pretty sharp blows to the setts which it happens to strike. This is caused by inequalities in the road, particularly at the joints of the stones, and the same thing happens more or less in connection with every kind of traffic, no matter how heavy and slow; and on every kind of pavement, no matter how hard and smooth. The stones are thus ground or chipped away, besides being gradually knocked out of position and forced down into the substratum. Vehicles act chiefly, though not altogether, on the surface of the setts, but horses principally chip off their edges, and give them a rounded shape, by their endeavors to get a firm foothold. This is proved by the fact that between tramway rails, where the setts are chiefly exposed to the action of hoofs, they become more rounded on the top than those subjected to general traffic in adjacent parts of the street. On a smooth, hard surface, there is comparatively no jolting and little abrasion, and, by reducing these, we shall evidently save material and lengthen the period during which the road will remain in good form.

2. *Minimum Wear of Vehicles.*—The wear of vehicles must no doubt be an important item, though it is not easy to estimate. Jolting is at least as bad for the vehicle as for the road, and a considerable sum can be saved to the community by making hard, smooth roadways.

3. *Minimum Noise.*—This becomes a desideratum where the traffic is incessant.

4. *Minimum Draught.*—The effects of different degrees of hardness and smoothness on draught have often been experimentally determined, and the results practically agree, though obtained in different places and at various periods. A few of them may be referred to here, as they conclusively show the importance of these qualities. At the Royal Agricultural Society's Bedford Show last summer, the average draught of seventeen carts was found to be 39 lb. per ton on a macadamized road, at $2\frac{1}{2}$ miles per hour, and 140 lbs. per ton on a field at $2\frac{3}{4}$ miles per hour. Sir John MacNeil's results are rather higher, being 46 lb. to 65 lb. per ton on macadam, and 147 lb. per ton on gravel; but such small differences need not surprise us, when we consider the impossibility of making the experiments in precisely similar circumstances. Other instances might be given, in which it was found that the draught was increased from 3 to 5 times, by allowing roads to get into bad order, or by putting on new metal.

For the sake of comparison, it may be mentioned that the draught on a railway, which is merely a very perfect kind of road, would probably not exceed 10 lbs. per ton. Now, diminished draught means, that each horse is enabled to do more work, or to do the same amount of work, with less exertion and straining, and, in either case, there will be considerable saving to their owners. Such considerations prove the advantages of having the least possible draught, and show that it can be obtained by making road surfaces hard and smooth.

5. *Cleanliness.*—We have seen how rough roads are worn away by the traffic. Now, the small *débris* ground and chipped off the material, forms mud or dust, according to the state of the weather. To a certain extent mud is also caused by the subsoil working up through the joints of the stones. But however caused, their evil effects are manifold. Dust, especially in cities, often consists to a large extent of poisonous organic particles, which people are apt to inhale. The poor cannot keep their houses clean if they are constantly going out and in with dirty clothes and boots; and we all know that cleanliness is essential to social well-being. The rich suffer too. Their furniture is often destroyed by the dirt. Shopkeepers also frequently lose considerable sums, owing to the injury it does to their goods. Moreover, mud is very injurious to the road itself. A clean road wears better than a dirty one. From what has been said, it will be seen that the quantity of mud carted away is a measure of the rate at which the material of the road is being consumed. Thus, in Dublin at one time the quantity of mud annually removed was greater than the quantity of metal annually laid on; and accordingly, the surface of the roads was gradually being lowered. Again, when machine-sweeping was introduced into Manchester, owing to the reduced cost certain streets were swept three times as often as formerly, but the quantity of mud removed was only 4 per cent. greater; and in other towns, where the machines were used and the number of sweepings increased, the quantity of mud removed was actually diminished. Mud keeps the road damp, and this softens the subsoil, making it work up through the joints, and thus increasing the amount of dirt to be removed. Besides, when the subsoil is in this damp, soft state, the setts are readily forced into it, and the road-surface becomes uneven and full of holes. By keeping the road wet, mud also facilitates the grinding down of the stones, as a supply of water materially aids this process. But we must return to our list of qualities.

III *Solidity.*—A road must have a firm substance, capable of resisting the weight of the traffic. A certain amount of bulk is necessary, because a pressure may crush a 3-in. cube, which would have no effect on a 12-in. one. The theoretical pressure of loaded vehicles does not vary much. Telford (probably founding his opinion on the practice of the time), thought it should not exceed 1 ton on each wheel, the tyre being 4 in. wide; that is 5 cwt. per inch of width of tyre. This opinion seems still to be held by cart makers, for at the recent Bedford Show, the average weight per inch of tyre was $4\frac{1}{2}$ cwt., the maximum and minimum being respectively $3\frac{1}{2}$ and $5\frac{1}{2}$ cwt. The weight of road rollers is about the same. Aveling and Porter's 30-ton roller exerts a pressure of about $5\frac{1}{4}$ cwt. per inch of width, and that of their 15-ton roller is only about 4 cwt. per inch of width. Pickford's vans and London omnibusses are exceptionally heavy, being sometimes loaded up to $8\frac{1}{2}$ cwt. per inch. Such are the calculated pressures in some instances, but it is difficult to say to what extent they may be increased, owing to tyres becoming convex.

IV. *Elasticity.*—The importance of this quality is perhaps not obvious at first sight, and as it is yet scarcely sufficiently recognized by road makers, I shall devote a few minutes to its consideration. Macadam thought that a certain amount of elasticity was esential to the endurance of his roads. He preferred a soft foundation, and noticed that a part of the road from Bridgewater to Cross, which was laid on a bog, and actually shook when a carriage went along it, consumed less metal, and was more easily kept in repair, than neighboring portions laid on limestone rock. He thought that a road was to some extent an arch, and supported the pressure of the traffic by its capacity of resisting inclined strains, as well as by its density. Telford, on the other hand, insisted on having a solid foundation, and seemed to ignore the advantages derived from elasticity. He held that a road was only a hard, solid body, which would prevent the wheels from sinking into the ground. Telford's system has been more generally adopted than Macadam's, though I think experience shows that the latter was right in endeavoring to make elastic roadways. It is now generally admitted to be most important that road coverings should possess this quality, and engineers have possibly come to this conclusion by observing railways. I have already remarked that a railway may be considered a very perfect road. The rails are hard, smooth, and solid, and carry enormous loads, moving at great speeds. Accordingly, whatever qualities are found to secure permanence and endurance in rails, will probably do the same for road-metal and pavements, though they may be required in a much less degree. Now, no one doubts the importance of elasticity in a permanent way. The only question seems to be, whether rails, and even wheels, should be made a great deal more elastic than they are. The Committee of American engineers on Rails, in their report, recently published, point out many ways in which it benefits the track, and I shall quote one or two of their remarks. "Too much stiffness diminishes the longevity of the rail. Inelastic road-beds are among the causes of rails becoming unfit for service. When the stem is too thick, the rail is too rigid, and this increases the wear on the head, and the liability to break. Rails in winter often break, because the bed is frozen hard." So far the report. But besides all this, it has been observed that rails laid on soft ground, such as a bog or an embankment, are more easily kept in good surface, and are easier to run on, than those which are laid on a hard foundation, such as a rock cutting.

Now, all these experimental facts prove that, as far as railways are concerned, elasticity is absolutely necessary.

But why? We have seen its effects, but how does it produce them? According to one authority it "absorbs the effects of the blows of the wheels," or in the words of another, "it neutralizes the vibration arising from the impact of imperfect cylinder rolling on imperfect planes." And this is no doubt the case, though the precise nature of the concussion, or impact, may not be well understood. The empty cab jolting along granite may serve as a very rude specimen of the kind of action which takes place on a railway. Probably it is caused by the combination of three things,—1st, high speed; 2nd, imperfect workmanship, owing to which neither rails nor wheels are quite smooth, and the latter are badly balanced; and 3rd, the elasticity of the materials employed. I fear the first two are not likely to be removed, and it is certain that the last never will. This concussion, therefore, appears to be a thing which we cannot get rid of, and which it is better and cheaper to meet, by giving considerable elasticity to rails and wheels, than by attempting to give them great theoretical perfection, that is to say, perfect smoothness and rigidity. Such an attempt would involve a large first cost, not to mention the cost and difficulty of maintenance. But whatever its nature, we have a rough idea of its amount, from the experiments of the Railway Iron Commissioners, in connection with wrought-iron bridges. They found that rapid motion might be supposed to add about one-third to the load, and acting on these results, it is the universal practice to make the working strain one-third or one-fourth of the breaking strain, according as the structure is to be free from or subject to vibration. In short, we find that Macadam early observed the value of elasticity in a road-covering, but that his ideas on this subject have not till recently been much acted on. We saw the importance attached to elastic rails by permanent way authorities, and having noticed these facts, we tried to ascertain the reasons which in the nature of things cause them. These we found to be great speed, imperfect workmanship, and the inherent elasticity of our materials. We therefore came to the conclusion that we cannot get rid of these causes which make elasticity essential to the endurance of permanent way, and that we ought to try to neutralize the unavoidable impacts, by giving more of that quality to rails and wheels, rather than by attempting to make them perfectly smooth and rigid.

Finally, all this applies in a less degree, but still a perfectly sensible degree, to roads. We are therefore led to suppose that elasticity will prove beneficial to road metal and pavements. This has been found to be the case, and the more this principle is acted on, the more this result will be confirmed. The chief benefit of elasticity is seen in the road itself; indirectly, however, it is advantageous to carriages, and this also can best be seen in railways.

V. *Durability.*—The importance of this is so obvious, that hardly anything needs to be said about it. Repairs are not only costly, but in crowded thoroughfares they inconveniently obstruct the traffic.

VI. *Rapidity of Construction*, so that it may be quickly laid down, and soon opened for public use. One concrete road was shut up for a month, that it might have time to set thoroughly. But such a thing could never be allowed in a crowded thoroughfare.

VII. *Capability of being easily lifted*, to give access to water and gas pipes, and sewers. This operation should be executed quickly, so as not to interfere with the traffic, and the roadway should not be liable to receive injury from having a part cut out and replaced. The introduction of subways has enabled us to dispense with this quality in some towns, but there are still many places where it is of great importance.

VIII., and lastly, *Roughness.*—A road should be sufficiently rough to afford foothold for horses.

Such are the qualities which, when combined, make a good road. Now, in looking over our list, we cannot but be struck by the fact that some of them appear to be incompatible with others. Thus, it is not obvious how a road can be hard, solid, and durable, as well as elastic and easily taken up for repairs. Nor is it evident how smoothness can be combined with the roughness necessary to give secure foothold. No doubt these requisites are opposed to each other, and herein lies the difficulty of making a satisfactory pavement. But this is not an exceptional difficulty. On the contrary, engineers continually have to sit in judgment on the relative importance of conflicting and incompatible objects. In such circumstances they must trust to practical sagacity, or to a kind of intellectual instinct not easily described. By means of this, even more than by their perseverance and energy, the founders of our profession accomplished their great works, though without many of the advantages we possess. But our advantages cannot make up for the want of this moral faculty, and unless we diligently cultivate it, we shall not be able worthily to follow in their steps.

On examining our list of qualities more minutely, I think we shall notice that the interests of those who make and maintain roads are identical with the interests of those who use them, or in other words, that the interests of trusts and vestries are the same as those of the public. A road and wheel may be considered two parts of one machine, and it is usually advantageous for all parties concerned that a machine should work as easily as possible. Referring again to railways for a moment, we shall see this more clearly. Rail and wheel are obviously two parts of one machine, and accordingly it is found that whatever does harm to the one injures the other also. Thus, whenever the platelayer complains that a particular engine is destroying his road, the driver of that engine is sure to complain that it is being destroyed by the road. But we shall confine our attention to trusts and the public. The latter body does not like noise, nor dust, nor mud, nor unrolled metal. Neither should the former. For noise is simply an audible sign that a process of hammering and grinding is being vigorously applied to the road; and the presence of mud or dust clearly shows that its material is being rapidly consumed. These things indicate bad construction, either in the arrangement or choice of materials. It has been already remarked that clean roads are more economical than dirty ones, and that constant sweeping effects a saving on the cost of maintenance. Rolling will be referred to further on, but I may here state that as well as making a smooth surface, it saves a considerable proportion of the cost of repairs. Roads of some kind are a necessary of life, but good roads are not an expensive luxury. On the contrary, they are the cheapest form in which this indispensable means of communication can be procured.

I shall now proceed to the second part of my subject, and describe very briefly the four modern kinds of roads, comparing the relative advantages and defects of their respective coverings, and calling your attention to the more important details of construction.

I. *Macadam and Macadam Concrete.*—Roads of this kind were introduced by Macadam and Telford, and I have already stated their respective theories on this subject when treating of elasticity. Telford's method of construction has been most generally adopted, not I think because it is in itself the best, but because it is the easiest. The success of Macadam's chiefly depends on very careful workmanship, and therefore it has perhaps hardly received fair play in other people's hands, though it appears to have worked well when carried out under his own supervision. But, without further reference to history, I shall now shortly indicate the details of construction, which in the present day seem to me of most importance. I think, then, in the first place, that Telford's paved foundation is injurious, because it deprives the road of elasticity, and is in fact a kind of nether millstone, upon which the covering is ground down. The top metal must be carefully selected. It should be tough and hard, not brittle, and not liable to disintegration by the weather. It should be broken evenly, because large stones are liable to be worked upwards by the agitation of traffic, and leave spaces, which hold water and prevent consolidation. The pieces should be cube-shaped, because this is the strongest form, enabling them best to resist the weight of the traffic and the splitting effects of frost. Machine broken metal, when first introduced, was very defective in this respect, the pieces being split into long thin rectangles, but this fault has now been to a great extent remedied. If the metal is too small, the wheels will sink into it; if too large, they cause jerks, and so break it. Macadam thought that the cubes should weigh not more than 6 oz., or, what is the same thing, should pass through a 2½ in. ring, and this size has been generally adopted, so we may assume that it is about right. It would be possible, however, to consolidate larger metal if the roads were rolled, and this would make them stronger, as well as save labor. Blinding ought certainly to be applied. There is a little confusion about this term, some writers using the word "blinding," apparently from an idea that it better expresses what is meant. "Blinding" is however precisely the same word as "blending." To blend originally meant to mix, and "blind" has acquired its ordinary meaning from the fact "that mixture causes obscurity." "Blinding," therefore, when it denotes the sand or fine gravel put upon a road, is used in its original sense, and implies that the material so named should be thoroughly mixed amongst the stone, so as to fill up the empty spaces. This is exactly what it is meant to do. The interstices of the covering must be filled up before the road can become perfectly hard and solid. And this must either be done by supplying sand, or by allowing the traffic to grind sufficient fine stuff out of the metal. If not sufficiently blinded, the stones roll about and get rounded, which prevents their ever binding together properly. If blinded too much, the road soon partially consolidates, but is always soft, and extremely muddy and dusty, because it consists to a large extent of sand. A rough notion may be formed as to the proper quantity of blinding to apply. It depends chiefly upon the amount and effect of rolling, and must be determined by experience, but the following reasoning may guide us generally. In a layer of road metal there are voids to the extent of 40 per cent. By rolling, at least half of these interstices would be filled up, owing to the pieces of metal being pressed together. Twenty per cent. of the metal would therefore be sufficient blinding, and in fact it is usual to supply from 17 to 25 per cent. But it will be seen that unless rolling is attended to, 20 per cent. of empty space will remain, which must be filled up by attrition from the metal. Two of the advantages derived from rolling have been already referred to. The whole subject is of great importance and interest, and is very fully discussed in Mr. Paget's report to the Metropolitan Board of Works, on the Economy of Maintenance which it produces. For further information I must refer you to this pamphlet, and can only here state, that by steam rolling 50 per cent. of the annual cost of maintenance is saved, chiefly owing to the great reduction in the quantity of metal consumed, while at the same time the work is done more rapidly, and is of better quality.

Macadam roadways have many good qualities, but there is one most serious objection to their use in towns. The metal wears so rapidly, that they are always covered with mud or dust, and can only be maintained in good order by constant and expensive repairs. In London it is the practice to lay down pavement whenever the annual expense of maintaining macadam reaches 10d. per superficial yard. In these circumstances the first cost of paving is always repaid in a few years, by the reduced outlay required in maintenance.

Obviously this system can be modified in various ways, by adding cement to the metal. Thus, either the foundation or the top metal, or both, can be made into concrete. This has frequently been done. The roadway of part of George IV. bridge is an old example of macadam concrete. This was laid in 1866, and seems to have stood well, but is now much worn on the surface, owing, I think, to its great hardness and rigidity. Mr. Proudfoot, the engineer to the City Road Trust, by means of the steam roller and a machine for mixing the cement—also by careful attention to the selection of metal and workmanship, has succeeded in producing much better roads of this kind. I fear, however, that they are deficient in elasticity, and would therefore wear rapidly if exposed to heavy traffic. The long time which the cement takes to set—generally about a month—during which the street must be shut up, is also a serious disadvantage. But these objections may not be important in many cases.

On the whole, we may conclude that macadam and macadam concrete roadways, although they may answer well in secondary streets, should not be laid in main thoroughfares. We may also conclude that neither this system of road making nor any development of it, is likely to produce the street of the future.

II. *Stone Pavements.*—Macadam has hitherto been generally superseded by granite pavement, when its maintenance became too costly. Little need here be said about the construction of these pavements, because residents in a town have frequent opportunities of observing the whole process. A few points may however be noticed. A good solid foundation is essential, otherwise the setts get forced down into it, and holes are formed in the street surface. The more holes there are, the greater is the wear of the setts, owing to the chipping and attrition caused by the traffic. Water also lodges in them, and tends still further to soften the foundation. The stones themselves should not polish easily, but remain rough on the surface. They are usually rectangular blocks, 8 in. to 16 in. long, 7 in. to 9 in. deep, and 3 in. to 5 in. broad. The smaller thickness gives the best foothold, but may weaken the sett, and the ordinary size is 4 in. to 5 in. Pavement of this kind is sometimes laid on concrete, and the joints fronted with cement and sand. This makes a very firm road. Bituminous concrete has also been used with stone setts. The chief objections to streets of this kind are their slipperiness, particularly when only a little wet, and the noise; also, I think, the want of elasticity. The effects of the absence of this quality are seen, whether the foundation is hard or not. If hard, the setts are rapidly worn away and rounded. If soft, they are driven down into it, and the surface is destroyed. An attempt was made to remedy this defect at Euston Station about 1843, by Mr. Taylor. Mount Sorrel granite setts only 3 in. or 4 in. deep, 3 in. wide, and 4 in. long, were laid on a carefully prepared foundation, consisting of three layers of gravel, each 4 in. thick, and carefully rammed. The setts were dressed and squared, and when laid were rammed with a 56-lb. wooden rammer. This pavement was found to be very impervious to wet, and very quiet, and, owing to its elasticity, the stones did not polish or wear much. Unfortunately the success of this method of road making, like Macadam's, depends too much on mere workmanship, and, when applied to an ordinary street, it failed. Part of Watling-street was paved in this way, and stood well till destroyed by sewerage operations. Granite pavement has no doubt been a most useful kind of street covering, but it is hardly up to the standard of excellence demanded by the civilization and luxury of the present day. I must say I think the public are not unreasonable in their demands, and have a right to ask for something better, considering the progress now made in all departments of engineering.

III. *Wood Pavements* have been tried in London at various periods since 1839. The best kind is that of the Improved Wood Pavement Company. It consists of fir blocks 3½ in. wide, 10 in. long, and 6 in. deep, set on end upon a double flooring of fir planks laid crosswise. The blocks are laid touching one another, so as to key across the street, but at the sides they are kept apart by ¾-in. fillets nailed to the planks. All the timber is well pitched, and the joints are grouted with some kind of bituminous concrete. Specimens of this roadway may be seen in Queensferry-street, and Forrest-road

IV. *Asphalt* was introduced into London for paving purposes in the year 1869. Several varieties have been tried, but the compressed asphalt of the Val de Travers Company has been found to be superior to all others, and is the only one which need engage our attention. It is a natural product, found in Switzerland, and the following is the method adopted in constructing pavements of it: A concrete foundation is first made, and on this the asphalt in the form of a heated powder is laid, to the thickness of 2 in. or 2½ in. Specimens of this kind of roadway may be seen in Kirkgate, Leith, and Gordon-street and Hope-street, Glasgow.

Wood and asphalt pavements are in several respects superior to granite. Much less mud and dust is formed on them, and they are comparatively free from noise. They are also safer, except when thoroughly wet. I am not aware that granite is in any respect superior to either of them. Even if they should turn out to be more costly, owing to their requiring repair more frequently, and having to be renewed sooner, I think the advantages already mentioned will more than compensate for the extra price. Only long and extensive experience can settle this point satisfactorily, because many indirect benefits are secured by their use, which it is not easy to estimate in money;—and there are many expenses connected with all pavements which are not usually included under the head of maintenance. On the whole, it seems probable that either wood or asphalt is destined gradually to supersede granite as a paving material, at least in large and wealthy towns.

It therefore only remains for us to find out which of them makes the best, or, to quote the *Pall Mall Gazette*, the "least objectionable" road surface. Mr. Haywood has fully reported to the Commissioners of Sewers of the City of London, as to the relative advantages, together with the probable expense and durability of these pavements. In 1873 he made a very extensive series of observations, in order to ascertain their relative safety. It is, however, difficult to make observations on different streets in such a way as to admit of their being fairly compared with one another, because safety varies so much with the weather, and also depends to some extent on the gradient of the street, the speed of the traffic, the state of surface repairs, and cleanliness. But, allowing for all these modifying influences, he found that wood is safer than asphalt, as not only fewer accidents occur on it, but those which do happen are of the kind least injurious to horses and obstructive to traffic.

Further, Mr. Haywood considers that wood is the most quiet, but also the dearest; that they both can be kept equally clean, and will probably be found equally durable. That they can be laid and repaired with about equal facility but that the best repairs can be made in asphalt.

The general impression left in reading the report, is that except as regards safety, there is not much difference between them. Wood is, however, about twice as safe as asphalt. It must also be kept in mind that the cost and durability is estimated from the tenders of the contractors, not from actual experience.

So much for the practical results. Let us see which of these two pavements is likely to endure best, judging from theoretical considerations alone. Wood pavement is constructed according to Macadam's principles, asphalt according to Telford's. Wood is laid on a comparatively soft foundation, and the whole roadway forms a kind of elastic arch, which partly resists vertical pressure, by distributing the thrust horizontally through its entire substance. In asphalt roadways, on the other hand, the concrete foundation may be considered the real road, the asphalt being merely a sort of protection, which gives a smooth surface, and can be easily renewed as it is worn away. But this combination is, I fear, devoid of elasticity. Elasticity is without doubt essential to the permanence of a roadway. This quality certainly appears to be secured in improved wood pavements, though not in asphalt. But it may be contended that the asphalt covering has in itself sufficient elasticity, and that it acts like a sheet of vulcanized india-rubber. Possibly a concrete bed covered with a sheet of vulcanized india-rubber might form a good road. I think a less yielding surface is desirable, and that elasticity of form is likely to give better results than mere elasticity of volume. For these reasons I venture to think that improved wood pavement will ultimately be found superior to Val de Travers asphalt, and that the introduction of the former has been a decided step in the right direction. I also think that we may look for further improvements in modifications of this system, and that a roadway having the requisite surface qualities combined with elasticity of form, will always be superior to one whose chief recommendation is mere solidity.

I fear I have wearied you by the great length of this paper. My excuse must be the extensive nature of the subject, and I can only assure you that much important matter has been unavoidably omitted. For instance, no reference has been made to various improved systems of street sweeping and watering. I have thought it better to confine statements of cost to a tabular appendix, so as not to confuse the text with numerical statements, also that the figures may themselves be more easily compared. Finally, I wish to take this opportunity of thanking Professor Fleeming Jenkin, Mr. Proudfoot, and Mr. Graham Smith for assistance which they have kindly given me in various ways.

COST OF ROADS AND STREETS IN DISTRICTS NEAR EDINBURGH, GLASGOW, AND CARLISLE, ALSO IN LONDON.

I. *Macadam and Macadam Concrete:*

Country roads, 1861–1874, per sup. yd. 1s. 2d. to 1s. 6d.

Town roads, founded on shivers, or hardest stone:

	s.	d.
15 in. metal, 1871	1	9
16 in. " 1874	2	4
18 in. " 1873	2	11½

Whin metal, 2 in. to 2½ in.:

Average price, 1861–1874, per cub. yd. 4 10

Price in Edinburgh, 1874, per ton, 5s. 9d. to 7s. 3d.

Note.—One cub. yd. whin metal weighs 27 cwt., and contains 40 per cent. of voids.

In London:	s.	d.
Granite 5 oz. metal costs (1870) per ton	16	0

1 cub. yd. granite weighs 24 cwt.

Cost of maintaining macadam, per sup. yd 1½d. to 3s. 3d.: average.... 0 6

Wear on Westminster bridge per ann. 5½ in.

Ditto, ordinary, do. 1 in. to 2 in.

Note.—When maintenance of macadam reaches 10d. per annum, pavement is cheaper.

Macadam Concrete in Edinburgh:	s.	d.
Mitchell's, 1866, per sup. yd	6	8
Proudfoot's, 1874 "	9	0

II. *Stone Pavements:*

Granite on shivers, 1874, per sup. yd..........10s. to 12 0

Ditto, concrete, 1872, per sup. yd....14 0

In London (averages):

Granite, on shivers, per sup. yd......18 0

Lasts for seven years.

Wear per ann., Aberdeen granite, ⅛ in.

Cost of repairs per ann. per sup. yd.. 0 3

Cost of pavement and repairs per ann., per sup. yd... .... 2 10

1.3 per cent. of first cost required for repairs, per sup. yd. per. annum.

Note.—In estimating the cost of granite pavements, allowance must be made for value of old stones.

III. *Improved Wood Pavement:*

London contracts. Company to maintain 1 year free, and 15 years at 1s. 3d. to 1s. 6d. per sup. yd. per ann.

First cost, per sup. yd........16s. to 18 0

Cost of repairs and pavement, per annum, per sup. yd ......2s. 2d. to 2 6½

Terms offered by company. Maintenance 1 year free, and 15 years at 9s. to 1s. 6d. per sup. yd. per annum.

First cost, per sup. yd........15s. to 16 3

Cost of repairs and pavement per annum, per sup. yd... ...1s. 7¾d. to 2 5

IV. *Val de Travers Compressed Asphalt:*

London contracts. Company to maintain 2 years free, and 15 years at 9d. to 1s. 6d. per sup. yd. per annum.

First cost, per sup. yd.........16s to 18 0

Cost of repairs and pavement per annum, per sup. yd........1s. 7¼d. to 2 4½

Terms offered by company in Scotland. Maintenance for 2 years free, and each year after at 3d. to 9d. per sup. yd. per annum.

First cost, per sup. yd...............15 0

Cost of repairs and pavement for 17 years, per annum........1s. 1¼d. to 1 6½

THE ECONOMIC USE OF BLAST-FURNACE SLAG.

By PERRY F. NURSEY.

From "Transactions of the Society of Engineers."

There was a time in the history of the arts and manufactures—and that time is well within the memory of the youngest member of the profession—when every department had what were termed its waste products. In some instances this waste was an unconscious one, unrealized by those whom it most affected. In others, however, manufacturers possessed a knowledge of their loss, but strove in vain to lessen or prevent it. Especially was this the case in metallurgical science, where, almost from the first, the value and usefulness of many waste products were fully recognized, and where continued efforts were made to utilize them. It is but a few years since that the gases of the blast furnace were truly yet regretfully looked upon as waste, but for which at length inventive talent found a profitable application. And so in other departments of manufacture, the rapid development of mechanical and chemical science has led to the successful application of waste substances in directions previously but little hoped for, if not wholly unthought of. And thus to-day finds some of the most simple of our industrial processes, each the parent of a variety of others, all more or less beautiful in their conception and happy in their practical results ; all tending to promote and sustain commerce, and to enrich the nations of the world. Witness the ultimate results of the destructive distillation of coal, or the more recent perfect utilization of the hitherto valueless waste produced in the manufacture of spun silk. The term "waste products" is now all but expunged from the vocabulary of applied science, and that of "bye-products," so pregnant with meaning, has by common consent become its valued substitute. Manufacturers, instead of seeking how best to rid themselves of what they in their ignorance deemed a nuisance and an incumbrance, are now for the most part busied in devising methods for its careful retention, with the view to its ultimate conversion into substantial profit.

One of the most expensive, cumbersome, and until recent years, useless products in the metallurgy of iron is the slag of the blast furnace. The yield of this substance from the Cleveland blast furnaces is about half as much again as that of the iron produced, while its bulk is more than three times greater than that of the metal. In the hematite districts the proportions of slag and iron are about equal. This mass of material absorbs and radiates an enormous amount of waste heat, which is so much loss of power. Hence attempts have been made to utilize the heat thus wasted, but without success. It is a heavy incumbrance, inasmuch as large tracts of land have to be purchased whereon to deposit it, the investment being of course wholly unremunerative. One iron manufacturing firm at least within the author's knowledge is exempt from this tax upon its capital, and that is the Hudson Iron Works in the United States, where the slag is used to fill in shallow bays. Thus, instead of having to purchase land for the deposit of the slag, the latter is actually utilized for the formation of land. Again, it is a source of great inconvenience at the blast furnace, accumulating there as it does in a hot, viscous mass, difficult to handle, and requiring special tools for removal. In fact, the labor spent upon this unproductive substance often equals the whole productive labor of the blast furnace. No wonder, then, that from the first persistent efforts have been made either to utilize it or to get rid of it altogether. The variety of schemes proposed for either or both of these purposes has only been equalled by the ingenuity displayed in devising them.

The refractory character of blast-furnace slag pointed it out in very early times as a suitable material for road-making, and it was thus first used, being broken up by hand for the purpose. But the demand in this respect is comparatively limited, and falls so infinitely short of the supply, that our slag heaps have gone on steadily increasing in bulk until at old-established works they have attained enormous proportions. In some Continental States, where stone is scarce, slag plays a prominent part in road-making, where it can be procured in large quantities. In Silesia, and other similarly situated countries, careful attention has been devoted to the treatment of slag, in order to render it as suitable as possible for road-making, being the only available material for that purpose. The great brittleness of slag is one of its objectionable features, so that in the first instance attempts were made to devitrify it. This implies a supply of cheap fuel, otherwise the process would prove too costly. As cheap fuel is scarce, devitrification is in some places successfully effected by allowing the slag to accumulate around the blast furnace, and to cool slowly under considerable pressure. This method is adopted at Tarnowitz and other districts in Silesia, where the slag accumulates to a thickness of 18 inches before removal. The process is, however, imperfect, only the lower half becoming devitrified ; but it nevertheless furnishes a good road-making material.

Another direction in which attempts have been made to utilize slag is to adapt it for constructive purposes. In the Cleveland and some other districts the slag is run into moulds and afterwards used for foundations, embankments, reclaiming land from the sea, and for similar purposes. In the Black Country the author has seen walls, and even houses, built up of moulded slag blocks, and they have in some instances presented a very pleasing appearance, owing to the variegated nature of the slag, but in all these cases there is a limit to the application, whilst there at present continues to be no limit to the supply of the material. Attempts have been made to utilize slag for ornamental purposes, by running it into moulds and afterwards annealing it ; but the latter process was found to be too costly, and this anticipated source of relief proved to be but one of disappointment.

In some Continental countries building stone is very scarce, and as slag appeared to contain the elements of a good building material, it was submitted to seemingly endless experiment, attended by apparently endless failure. In time, however, success came, and the result was the production of a very useful material for certain kinds of construction. The process of manufacture as carried out at Königshütte, in Silesia, consists in running the slag from the furnace into a hemispherical basin on wheels. The bottom of this basin is covered with sand or fine coke dust to the depth of about $1\frac{1}{4}$ inch, and the wagon is drawn to the point where the bricks are to be made. The slag and sand are mixed together with a curved iron tool until most of the gases have escaped and the mass is about the consistency of dough. It is then drawn with the same tool into a mould with a hinged cover, and punctured several times to let out the gas. The cover, which fits into the mould, is then turned down, and the slag becomes compressed. By the time three or four moulds have been filled, the first slag brick is sufficiently solid to be removed. This is done by raising a clamp, which allows the mould to separate. The red-hot brick is now drawn into a kiln, covered over with powdered coal and left to anneal. Each kiln contains 1,000 bricks, and is from three to four days in cooling. Four men can make 500 of these bricks in three hours. The loss in the manufacture from breakage is about 20 per cent. These bricks are rough on their surfaces, but on account of their larger size do not require more mortar than an ordinary brick. They do not readily absorb moisture, and for that reason are extensively used in the construction of foundations. In Silesia, these bricks cost 25 per cent. less than an ordinary brick.

In the Hartz mountains the lead-furnace slags, which are silicates of iron, are run into moulds and compressed, thus forming bricks for building purposes. They are, however, of inferior quality, being very brittle, and houses built with them are usually quoted with compo. One of the first successful attempts on the Continent to transform slag into a useful building material was made by M. Sepulcre, a Belgian engineer. His process consists in running the slag into pits having the sides inclined at an angle of about 30 degrees. This quick increase in the sectional area of the pit allows the solid crust which forms on the top of the slag to rise with it without becoming attached; the whole mass of slag is thus liquid, and solidifies from above and under pressure, being left several days to cool. When first turned out the stone thus produced can be readily broken into any required shape; but it gradually hardens on exposure to the atmosphere. The primary conditions of success with this process are that the furnace is in good working order, and that the slag contains about 40 per cent. of silica. If lime be present in excess, the stone will crumble to pieces on exposure. From experiments made by the "Conservatoire des Arts et Mètiers," in Paris, with the stone produced by M. Sepulcre's process, it was found that when made from the slag of grey iron it became fissured at a pressure of 3,100 lbs. per square inch, and was crushed under 5,700 lbs. Stone made from white iron showed fissures at 3,450 lbs., but it did not give way until a crushing strain of 12,600 lbs. per square inch had been reached.

Another application of blast-furnace slag on the Continent is that of glass manufacture. In Belgium, experiments in this direction proved so successful that it led to contracts being entered into, by the glass manufacturers in some parts of the country, with the proprietors of blast-furnaces for the regular supply of slag for this purpose. The only preparation necessary is to run the slag out on to iron plates and to cool it with water. By far the most general method of dealing with slag is to granulate it with the view of its ultimate adaptation to constructive purposes; and this course of treatment is carried out in various ways both in England and on the Continent. When in Belgium a short time since, the author visited, amongst other industrial establishments, the ironworks of M. Dallemagne, at Sclessin. There the slag is granulated in a very simple manner. On being run off from the blast furnace it is made to pass through a stream of water, which has a sufficient velocity to carry the grains of slag into a pit, from which it is raised and delivered into wagons by an endless chain with buckets attached. The water enters under the slag and the steam formed at the junction of the two is said to materially assist in breaking up the slag. The only labor required is that of a couple of boys, who occasionally agitate the mixture of slag and water, one at the point of entrance and the other near the buckets. The invention of this simple process of disintegrating slag, which is extensively used in Belgium and France, is said to be due to M. Minary, director of the Franche-Comté Iron Company. In these works, which consist of five blast furnaces, each producing 20 tons in twenty-four hours, the introduction of the system resulted in the saving of the wages of twenty men who were previously occupied in charging the slags, and of five blacksmiths who repaired their tools. The saving effected is from 5,000 to 6,000 francs per annum. Beyond this saving, however, there is another absolute gain afforded by the utilization of this granulated slag in various departments of the works. The first uses to which granulated slag was there put were as a substitute for gravel, and for making the bed of the casting-house. The pigs came out of these beds very clean and bright, and were preferred by the puddlers even to those cast in iron moulds. This method of using the slag is now of almost universal application in the Siegen district in Prussia, where most of the furnaces run on spiegel. The cleanness of the pigs cast in slag beds suggested its partial application to moulds for fine castings. The fine dust was sifted out from the granulated slag, and with it the moulds were sanded, the result being that the castings turned out better and cleaner than before. As may be supposed these applications only consumed a very small portion of the slag; the surplus was therefore offered to the railway companies, and they find good use for it as a ballast, paying a moderate price for it; the foundries thus obtained a revenue from what had previously been but a source of continual expense. It is stated to make a good ballast; being porous it retains but little moisture and packs very well.

From the first moment that the granulation of slag became an accomplished fact its substitution for sand in construction suggested itself, and its use in this respect has been attended with very good results. It was first mixed with lime and used as a mortar, and some having been left from a job was soon afterwards found to have become very solid. This was suggestive of further applications—the preparation of concrete and the construction of foundation walls. To both of these purposes it has been successfully applied. Then followed the idea of manufacturing bricks, and the proprietors of the Georgs-Marienhütte, in Hanover, mix the granulated slag with lime, press and sun-dry the bricks moulded therefrom, and have used them very largely in the construction of their buildings. They cost much less than the ordinary bricks, and being almost white give a light, cheerful air to the buildings. Another application of granulated slag consists of coating the surfaces of unburnt bricks with it, and burning them out of contact with coal. This produces an enamelled face—an appearance which is much sought after in some places on the Continent. By the admixture of slag sand with fire clay the quality of the bricks made therefrom is said to be greatly improved. This suggests the application of the sand in the manufacture of bricks for puddling furnaces, where a highly refractory material is still a desideratum. The possibility of manufacturing cement from granulated slag has been demonstrated at one of the largest ironworks in Germany, where experiments were carried on for several years with the view of determining the point. Large works have been constructed in connection with this foundry, where an artificial cement is manufactured which is said to be equal to the best Portland cement, and which is produced at a very low price.

The important part which carbonic acid plays in rendering soluble the various mineral substances required by plants for their growth, has led to the supposition that blast-furnace slags can be profitably applied for agricultural purposes. Whether German ingenuity has succeeded in the successful application of slag in this respect the author is not aware. That English skill has not been able to effect the object he is aware, as will presently be shown. Hitherto the author has confined himself mainly to the theory and practice of Continental metallurgists in the matter of the utilization of the slag of blast furnaces. He will now proceed to deal with the practical development of the question in England, noticing *en passant* such proposals bearing on the subject as are of interest or value. In this, the home department, as it may be termed, the author is able to supply information of a more precise and detail character, and to show by diagrams and models the exact form of apparatus used in producing given results, which results, moreover, are themselves illustrated by samples of the various products.

Amongst the earliest scientific investigators of the question of applying furnace slag to economic purposes was Mr. Bessemer, one of our honorary members. In the year 1863, Mr. John Gjers, of Middlesborough, also a member of our Society, patented a plan for granulating slag by running it into agitated water. The sand thus produced was used in place of siliceous sand on the pig beds. Mr. Gjers, however, informs the author that he gave up the practice because in Middlesborough no cover is used over the pig beds, and in wet weather some trouble was occasioned by the slag absorbing and retaining water. Moreover, sand is very cheap in that part of the country, and the ironmasters there failed to appreciate the advantages of having a good flux on their pigs rather than a siliceous sand covering, which does not tend to promote good yield either in the puddling or the cupola furnace. With covered pig beds Mr. Gjers experienced very good results.

In 1871, Mr. David Joy submitted to the iron trade of Cleveland a plan for shipping slag in blocks, differing somewhat from a plan proposed by Mr. Charles Wood a year previously to the Tees Conservancy Commissioners, not only for taking the slag to their breakwater, but also for removing it direct from the furnace by an endless band. Simultaneously with this a similar plan was projected by Mr. Thomas Bell, and soon after practically worked at Walker. Messrs. Smeeton and Bowler, Mr. Lurrman, and Mr. Homer also deserve honorable mention for the active part each has taken in promoting the solution of the slag difficulty. But, perhaps, no names have been more prominently before the public of late years in connection with the subject than those of Mr. Charles Wood, of the Tees Ironworks, Middlesborough, and Messrs. Bodmer, of the Spring Vale Brickworks, Hammersmith. Mr. Wood has designed and brought into successful operation machinery for the granulation and disintegration of slags, whilst Messrs. Bodmer, taking the results of Mr. Wood's process, have been no less successful in utilizing them for constructive purposes. Messrs. Bodmer have also devised a special method of reducing slags to a state of division of various degrees of fineness. Mr. Wood's disintegrators are of two kinds, horizontal and vertical; the former is used for reducing the slag coarsely, and the latter for producing a fine slag sand. It consists of a circular revolving table composed of thick slabs of iron. The table is kept cool by means of water which circulates through channels formed in the slabs. A set of scrapers are attached to a fixed arm carried above the table. The table is made to revolve very slowly and the liquid slag is delivered on to it, and forms its own thickness, varying from ½ to ¾ inch. As soon as the slag has parted with sufficient heat to become solid, water is allowed to run freely upon the surface, and by the time it arrives at the scrapers it is sufficiently cool to part from the tables readily and break up. It then drops into the slag wagons, and as each wagon is filled it is removed and another takes its place.

The slag-sanding machine is the reverse in principle of that just described; in shape it somewhat resembles a rotary puddler. Its sides, however, are only made sufficiently high to enable it to contain from 2 feet 6 inches to 3 feet of water in the bottom. This cylinder is kept in motion by a small steam engine, and the water is agitated by means of buckets placed inside the periphery of the cylinder. These buckets are perforated so as to act as screens, to separate the sand from the water. They also elevate the sand to the top of the machine, where it drops into a spout, and is conducted thence into wagons. The speed of the machine is about 100 feet per minute, or about four and a half or five revolutions, according to the nature of the slag. Thus, the water is kept in a violent state of agitation, and the liquid slag, which is run into it direct from the furnace, is instantly scattered in the body of water in the form of sand, the water taking up the heat and throwing it off again in the shape of steam. The action of the machine is so perfect that no crust nor any large pieces are allowed to form. On the table are samples of this slag just as it comes out of the machine. The slag is delivered in a constant stream into railway trucks, in a suitable condition for being dealt with for manufacturing purposes.

The next point for consideration is the manner in which the material thus produced is converted into a commercial article. There are four chief purposes to which granulated slag is applied: these are the manufacture of bricks, mortar, concrete, and cement, and chief amongst those who have persistently devoted themselves to the question of utilizing slag in these respects are Messrs. Bodmer & Co., who take up the question exactly where Mr. Wood leaves it, and so carry out the ultimate application of the slag in practice. After proving his machines to be a success, Mr. Wood sent some of the slag sand to Messrs. Bodmer, who, by mixing eight parts of the granulated slag with one of cement, produced a valuable brick, specimens of which are on the table. By Bodmer's process the sand requires no further manipulation than the mixing it with lime, and submitting the compound to hydraulic pressure. After two or three weeks' exposure to the air the bricks are found to be fit for use. In making mortar Mr. Wood uses five parts of the sand to one of lime, which, when well ground up together, form an excellent mortar, nearly equal to cement. By adding about 5 per cent. of ironstone to the mass, Mr. Wood has found that the strength of the material is greatly increased. Concrete is made by combining six parts of the rough slag from the first machine with one part of the mortar just described. The materials are worked up well and moulded into blocks, which are found to be very suitable for foundations and for the walls of cottages. Concrete made from Mr. Wood's rough slag mixed with Portland cement has been extensively used in carrying out the drainage of Middlesborough; and, as far as the author is informed, its use has proved very satisfactory. The manufacture of cement from slag has also been attended with good results, as will presently be shown.

An important consideration in determining the commercial success of any invention, and one to which the practical mind intuitively turns at the outset, is that of cost. It is satisfactory to find that in the utilization of slag, for the purposes mentioned, the question of cheapness in production has been placed beyond doubt, as shown by the following statement of facts, which have been compiled from actual working, and communicated by Mr. Wood to the author:

SLAG SAND.

Taking the make of the furnace at 25 tons of iron, there would be a yield of about 36 tons of slag. To convert this into sand the expenses would be—

	s.	d.	
One man, per day...	4	0	per shift.
8000 gals. (water) at 3*d*.	2	0	
Wear of machine....	3	0	
	9	0	× 12 ÷ 36 = 3*d*. per ton.

Concrete Blocks.

		s. d.
Rough machine slag,	8 tons,	4 0
Slag mortar,	1 "	4 0
	9 "	= 8 0
Labor, 1*s*. per ton........		9 0
		17 0 ÷ 9 = 1*s*. 11*d*.

1*s*. 11*d*. per ton, or ¾*d*. per cubic foot. If with ironstone, about 1*d*. per cubic foot.

Mortar from Slag Sand.

		s. d.
5 tons sand, at 3*d*.........	1 3	
1 ton lime, at 15*s*.........	15 0	
6	16 3 ÷ 6 =	2 8
Grinding		1 4
		4 0

Four shillings per ton.

Bricks

	s.	d.
2 tons 10 cwt. of slag sand a 3*d*. per ton..	0	½
Lime....	4	0
Wear of machine....	1	3
Coals and water....	1	0
Labor, &c....	3	2
Per 1000....	10	0

The following analysis of blast-furnace slag has also been furnished by Mr. Wood to the author:

ANALYSIS OF FURNACE SLAG.

Silica	38.25
Alumina	22.19
Lime	31.56
Magnesia	4.14
Protoxide of iron	1.09
Manganese	trace.
Calcic sulphide	2.95
	100.18

The author has already referred to the part taken by Messrs. Bodmer in converting the slag sand produced by Mr. Wood's machinery into bricks. But Messrs. Bodmer have done more than this; they have designed a system of slag reduction upon what may be termed the dry principle in contradistinction to that of Mr. Wood, which is on the wet principle. This system had been perfected after protracted experimental working at blast furnaces in Wales. A careful investigation into the properties of slag produced in the wet way led Messrs. Bodmer to the conclusion that there were conditions to which slag so treated was inapplicable. They found that sand obtained by running the slag into water consisted of large and small granules of a spongy porous character and very light. Carefully examined it would seem that the water causes the slag to form agglomerations of cellules, each of which encloses a certain amount of moisture. When heated the moisture becomes converted into steam, which does not escape, but recondenses upon the temperature being lowered. It is found to be practically impossible to dry such sand without previously pulverizing it. This spongy slag, when used as railway ballast, does not readily settle down into a solid compact mass, and hence arises an objection to it in this respect. It is, however, well adapted for certain descriptions of concrete and for brickmaking. How far its sponginess affects its resistance to compressive strain, the author is not prepared to state. In manufacturing bricks from spongy slag-sand, Messrs. Bodmer find it necessary to pulverize the sand before they are able to use it, in order that it may attain the requisite degree of dryness.

The object of Messrs. Bodmer therefore was to produce the sand in a dry condition, and they effect this end by passing the slag through rolls. The slag is delivered direct from the blast furnace into a pair of rolls, revolving either with equal or differential surface speeds. If the object is simply to obtain the slag in a convenient form for removal, the rolls are set wide apart; with rolls working at equal surface speeds the slag is delivered in the form of a continuous band of the same width as the rolls and about ¼ inch thick. The slag is either deposited in a truck direct from the rolls or fed upon a forwarding apparatus, as most convenient. With plain rolls moving at differential surface speeds, or with corrugated rolls, the slag is delivered in slabs. Slag produced in this manner, and without being brought into contact with water, retains its crystalline fracture and hardness, as will be seen by the specimens on the table. This condition is most favorable to its use for ballasting and for the manufacture of concrete. If the slag is required for the manufacture of bricks, mortar, or cement, plain rolls revolving at differential speeds are employed, the rolls being set a greater or less distance apart, according to the thickness of slag scale desired. When the slag on issuing from the rolls is allowed to drop into water, it is rendered amorphous without becoming spongy, and without the capacity for retaining water peculiar to spongy slag. Such slag being very friable, as the specimens on the table show, can be further disintegrated, if desired, with facility. With the rolls placed very close together and with considerable differential speeds a very fine thin scale is produced, especially suitable for the manufacture of slag cement.

In carrying out their process of disintegration Messrs. Bodmer do not employ any special mechanical arrangement. The rolls are of the ordinary type, about 25 inches in diameter and 20 inches in length. Beneath them is a moving shoot by which the rolled slag is fed either on to a chain belt or a bucket belt, which delivers the slag into the trucks. A pair of rolls of the dimension stated will take through about 94 cubic inches of slag ¼ inch thick per revolution, or working at a speed of thirty revolutions per minute, and the slag weighing 120 lbs. per cubic foot, 195 lbs. per minute, or more than five tons per hour. This rate of working is found ample to meet the exigencies of the greatest rush of slag. Messrs. Bodmer's method of preparing the slag has not yet been adopted in practice, but the author is informed that a license to work their patents in the Middlesborough district has been granted by the inventors to a company which has been formed in the iron districts for the utilization of furnace slag. The same company has also arranged to work Mr. Wood's patent.

In converting the slag into bricks, Messrs. Bodmer first feed that material into a hopper placed over the measuring apparatus, from which it issues in a uniform layer on a carrier belt. At the same time the lime and other cementing materials are each fed into a separate hopper and measuring apparatus, and upon issuing therefrom are passed together through a mixing apparatus, from which the mixture falls upon the traveling layer of slag sand. The cementing material and the sand are then passed in combination through another mixer, in which they are intimately incorporated. The compound is then delivered on to a traveling belt, by which it is conducted to the brick press. The whole of these operations, with the exception of the feeding of the hoppers, are automatically performed. The brick press is on the hydraulic principle, and is worked by a hydraulic force pump and an accumulator. It consists of a circular table revolving horizontally, and fitted with six pairs of moulds. Whilst four moulds are being filled, four others are under pressure, and finished bricks are being discharged from the remaining four, the processes being carried on simultaneously. The bricks are removed on barrows to the drying sheds, where they remain until ready for use. The time required for ripening is from three to five weeks, according to the character of the lime used, and according also to the weather. The press is worked at the rate of seven strokes per minute, producing therefore twenty-eight bricks per minute, or at the rate of 80,000 per week. For this production two men and four boys are required, exclusive of wheelers and pilers.

A series of experiments were made for ascertaining the degree of absorption possessed by bricks of various kinds. The bricks were dried on a heated iron plate and were then weighed. After having been immersed in water for fifty hours, they were again weighed, with the following results:

	Best Gault Clay Brick.	Best Stock Clay Brick.	Bodmer & Co.'s Bricks. Sand and Lime.	Blast Furnace. Dry slag.	Slag and Lime. Spongy slag.
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
Weighed dry	5 15	4 13	6 9¾	7 7½	5 7¾
Weighed wet	7 2¼	5 14½	7 1¼	7 12¼	5 14½
Water taken up per brick	1 3¼	1 1½	0 7½	0 4¾	0 6¾
Percentage of water taken up	20.26	22.72	7.09	3.97	7.69

The manufacture of cement from slag presents several features which are worthy of consideration. A great similarity exists between trass, a cementitious substance found along the banks of the Rhine, puzzolano, and blast-furnace slag, as will presently be seen by the results of analyses. Notwithstanding this similarity it does not appear that furnace slag has yet come into commercial use as a cementing material. It has, however, been made both in England and on the Continent, and has been successfully used by those by whom it has been made. But as far as the author can ascertain it has not yet become a regularly constituted article of commerce in any country. The reason for this appears to lie in the fact that unless the slag is disintegrated under pressure and out of contact with water the material is not in a proper condition for the purpose. Messrs. Bodmer therefore pass the slag through rolls closely spaced, and to produce a reliable cement from it they grind it to an impalpable powder in company with the lime. The slag must be perfectly dry and at the same time friable. The stronger the hydraulic properties of the lime used, the more reliable the slag cement becomes. Practice has, moreover, proved that the slag from a grey iron furnace yields the best results.

The following table gives the results of some comparative experiments with slag and Portland cements:

Figures taken from Experiments made on the Strength of Portland Cement by John Grant.			Experiments made with Slag Cement by Mr. J. J. Bodmer.		
Weight of Cement per Bushels in lbs	Age after Gauging.	Tensile Strain per square inch in lbs.	One part Lime and seven parts Slag by weight.	Age after Gauging.	Tensile Strain in lbs. per square inch.
106.7	7 days	157.6	....	....	....
107.6	"	156.56	....	....	....
111.75	"	201.63	....	....	....
114.15	"	269.78	....	14 days	271.22
119.04	"	248.03	....	....	....
119.07	"	305.89	....	....	....
121.0	"	409.77	....	....	....
"	14	472.26	....	1 month	470.18
"	28	499.51	....	....	....
"	2 months	522.44	....	....	....
"	3 "	558.62	....	....	....

The results were obtained under tensile strains, and the slag cement was composed of six parts of slag from a blast furnace producing No. 3 foundry iron, and one part of lime of medium hydraulic properties.

The following table gives comparative analyses of slag cement, trass, and puzzolano, and shows the similarity already referred to as existing between those substances:

	Blast-Furnace Slag.					Trass.	Puzzolano.
	Cleveland District.			Wales.			
Silica	36.2	40.75	34.0	49.50	45.0	57.	44.50
Alumina	26.	24.47	24.33	15.20	16.42	12.	15.
Lime	27.	24.50	34.0	19.70	26.78	2.60	8.80
Magnesia	9.	7.17	5.88	3.0	0.40	1.	4.70
Protoxide of iron	1.30	2.05	0.07	8.82	5.20	5.	12.
Potash	.....	.....	.....	.....	0.46	7.	1 40
Soda	.....	.. .	.....	.....	.....	1.	4.
Sulphur	0.4	0.65	1.72	1.29	.....	.....	.....
Water	.....	.....	.....	.....	.....	9.40	9.20
Protoxide Magnesia	.....	.....	.. .	.....	5.64	.....	.....

The applicability of slag to agricultural purposes, to which reference has already been briefly made, is at present very problematical. Although it contains ingredients which in themselves are fertilizers, it is questionable whether these substances exist in the proper form for assimilating with the soil. The lime in the lag, for instance, assumes the form of a silicate, a totally different condition from that in which it is used in agriculture. Mr. I. Lothian Bell, the President of the Iron and Steel Institute, himself a producer of blast-furnace slag to the extent of about 1,000 tons per day, informed the author that, being desirous of utilizing the slag, he granulated some and applied it on land where it was somewhat heavy. On comparing the crops on the land thus treated with those on similar adjoining land not dressed with slag, he could detect no difference whatever. It would, therefore, appear, that as far as this application is concerned, the conditions under which it may be effectively used have yet to be determined.

Another application, which, although it has proved to be more successful than the last, is at present quite as far from being adopted in practice, is that of a clothing for steam pipes. To produce the slag in a proper condition for this singular purpose, a blast of steam, water, or air is forced into the stream of viscous slag as it is run from the furnace. Thus treated the slag assumes a fibrous form similar to spun glass, and is known as "furnace wool." When the stream of slag is imperfectly acted on by the current directed against it small globules are formed about the size of shot. This fibrous slag is a bad conductor of heat, and has been used as a covering for steam boilers and pipes. Slag has also been used for adulterating emery powder.

Such, then, are the principles and practice of slag utilization, as they exist at the present time. The principles can hardly be said to be fully developed, nor the practice much more than in its infancy. Further investigation, for which their is room, will probably be found to modify present principles, whilst extended working will doubtless suggest alterations in practice, and both will add to the discovery of more numerous uses for slag. The author is convinced that these three things will result in time, s a natural consequence of the general desire to promote the economic use of blast-furnace slag, and thus to convert a source of absolute loss into a means of permanent profit. And what is true as regards the utilization of slag holds good also with respect to other substances which may now be treated as waste. Doubtless the progress of science, in promoting economy of working, will yet lead to the utilization of substances for which at present no satisfactory use can be found. All matter was but so much waste before the creative faculty of man provided appliances for its util zation. And so human progress will further show, that what is now the veriest waste, will, in the course of time, assume a condition of value. Thus will art be made to approximate to nature, in that she will know no waste.

In 1874 France produced 1,360,000 tons of pig (crude) iron, 760,000 tons of wrought iron, and 155,500 tons of steel.

The total length of tramways laid down in Vienna is about five geographical miles, and the service is conducted with 554 tramway cars and 1,864 horses. Ten per cent. is the dividend on the paid-up capital.

TOWN SURVEY OF KINGS COUNTY.*

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

A GLANCE at the chart of New York Bay and Harbor shows the City of New York, a county in itself, dropping down from the main land of Westchester County towards the bay, in the form of an elephant's trunk, with the Battery as its prehensile point. On the west side it is separated from New Jersey by the stately Hudson River, and on the east from Long Island by the East River, which is in great measure one of the mouths of the Hudson, emptying into Long Island Sound.

This form of the great city is significant, for the elephant to which it belongs, commercially, is not Westchester County, nor New York State, but a vast group of counties and States reaching westward to the Pacific Ocean, which draw through this trunk the products of the world beyond the sea, and in turn deliver up their wealth of production in New York Bay.

As a natural result of the commercial supremacy of this city and its noble harbor, its growth, with that of its environs, has been rapid and regular. At the last census (1870) New York numbered 942,292, Brooklyn 396,099, and Jersey City 82,546; whereas, in 1850, their respective population was 515,547, 96,838, and 6,856. But this does not represent the legitimate population of New York, since the facilities for suburban life have been so multiplied, to keep pace with the city development, that it is simply the main business center of a radius of thirty or forty miles, chiefly built up by its direct or reflex action, and aggregating millions of people dependent on its welfare.

There are several local causes for the growth of the suburbs of New York in keeping with, or in preference to that of the city proper. The city promontory or trunk is long and narrow in form, while its facilities for commercial work chiefly concentrate at the more southern and older part; the lower end therefore filled up gradually until the district below 23d street ceased to show increase at different census takings, and the upper city became the place of development. But this proved a very expensive place to develop, from the rocky and irregular nature of its formation, from the loss of area taken by the Central Park, and the contingent increase in property values. The question of time and comfort in transit came into play also, and the locomotive, with its swift and comfortable trains, gave to the cheaper areas of construction, and the charm of villa life, a powerful rivalry with the tedious stages and horse cars of the city proper, the excessive rents, and other living expenses. It is estimated that it has cost not less than $500,000,000 to put the streets and building lots of upper New York, such as they now are, into condition for use; and unimproved city lots six to eight miles north of the City Hall are worth the price of a comfortable suburban residence. This explains what the census of 1870 shows, that within a radius of forty miles New York contains 41¼ per cent., New Jersey 24¼, Brooklyn 17 and its suburbs 6¼, Westchester 6, and Staten Island 1½ per cent. of the aggregate population concentrated around New York Bay.

The immediate relation of this surburban life to New York City is singularly illustrated by the annual statistics of railway movement. In 1873, of about 37,000,000 passengers carried to and from the city, about 20,500,000 were by the New Jersey roads, 13,500,000 by the New York Central, Harlem & New Haven roads, and 3,000,000 by the Long Island roads. Of these the average receipt per passenger was, for the westerly lines 55 cents, the northerly 81 cents, and the Long Island 34 cents, showing an average travel for all directions of less than thirty miles. A result like this is significant to railway engineers and owners of suburban lands. It shows that the three great cities on the Bay represent little more than one-half the interested population, of which about 60,000

* Report of Samuel McElroy, C. E., Superintendent of Survey, submitted Oct. 31, 1874.

are in daily transit to and from New York. It also shows an annual exodus and growth, due to the rapid increase of the great center, equivalent to about 47,500 persons a year in the suburbs, on the average of twenty years past, an average which must be largely multiplied to give the actual exodus and growth of 1873 or 1874.

If we turn from this glance at the increase on New York Bay and vicinity to rapid survey of the suburbs themselves, around the three prominent cities, we see that New Jersey far surpasses the others in growth, although Newark Bay and the extensive marshes of the Hackensack and Passaic Rivers practically force expansion to more westerly districts; Westchester being rough and rocky, as is Staten Island, and both better fitted for summer than winter life. If we examine that large section of Kings County which lies on the easterly side of the Bay, with an average distance of about seven miles from the Battery, we find a country singularly favored in its natural characteristics. With a picturesque and commanding front on the Bay and Harbor, and direct communication with ocean commerce; with soil whose fertility is a proverb; with broad and easy slopes delivering towards the bays on the south and east, admirably adapted to street and house construction; with an abundant supply of the purest and softest water; with fine roads, attractive boating, bathing, fishing and hunting; with a population intelligent, industrious, frugal, long associated with the land, and generally affluent; in the whole radius of forty miles we have named, this area, which represents about 15½ per cent. in size, cannot be surpassed in advantages for suburban residence. Nevertheless, while within twenty years the other suburbs of New York have accumulated a population of not less than 870,000, which should give this section 133,000 increase, and still more from its proximity to the Bay; the actual increase from 1850 to 1870 is but 16,300 on about 41¾ square miles of unexceptional territory. If New York City is the active elephant's trunk which ministers to a whole nation, these five towns of Kings County lay comparatively supinely on the Bay and Harbor in the form of a huge turtle, with Red Hook Point for one claw, Coney Island Point for the other, and the Bay Ridge bluffs for its massive head.

There is a reason for this, and a very simple one. Through this whole area there is no direct steam railway communication with New York; no way in which, with regularity, frequency, comfort and speed, a business man can be carried to and from the city, as he can be carried in any other direction; and in consequence of this an acre of building lots in the rocks or swamps of Harlem, six or seven miles from the Battery, is worth twenty-five times as much to-day as an acre in Kings County no further away!

Of course the people of this district have been more or less touched by the spirit of the age. Various contiguous improvements in Brooklyn have made rapid increase in values near them, and brought increased population. Operators from Brooklyn or New York have here and there purchased farms for investment, and united with the farmers in urging local improvements. Several years ago, so many local plans of streets had been proposed, without any uniformity of interest, each owner cutting up his property as it suited him, and the necessity for organized development was so generally felt, that a Commission was appointed from the supervisors of the town, with the chairman of the Board of Supervisors, to lay out a general plan of streets, basins and bulkhead lines, over the entire area, all private plans being superseded by their authority. This Town Survey Commission of Kings County has now completed its work and filed its maps in the office of the Secretary of State and the County Register, with special maps in the office of each Town Clerk.

The general importance and magnitude of the work of this commission may be gathered upon the statement that about 2,289 miles of streets have been established, enclosing about 6,021 blocks, 320,700 building lots, with a possible population, at 7 persons per lot, of 2,244,900. In connection with this work, the bulkhead lines have been defined from the Brooklyn city line on the Bay to Fresh Creek Basin on Jamaica Bay, with plans of commercial basins adapted to the most economical methods of construction and safest wharfage; a ship canal is located from Gravesend to Sheepshead Bay; and eight interior basins are laid out, on lands now worthless as marshes, for future commercial uses, and to facilitate building improvements. The total cost of this work for four of the towns, covering $36\frac{3}{10}$ square miles, including maps of the fifth, was $73,119. The work of locating the street lines by monuments was done in 1871–2–3, the number set being about 2,800.

The immediate effect of this survey was to determine definite and systematic street plans, independent of local convenience. The district was studied carefully as to its present and future lines of development and movement, so as to obviate expensive future corrections. Respect was paid to established centers of population, but without destroying the harmony of the general plan which enveloped them. On this subject the following statement is made:

LINES OF MOVEMENT AND SYSTEMS.

A study of the experience of any old and populous city shows the great importance of placing the streets and avenues so that the blocks will range in lines parallel with those of greatest travel, and proper care in this respect is of great consequence to this portion of Kings County, which is certainly destined, in time, to contain a vast population.

The City of New York was treated by Jno. Randall, Jr., C.E., in the general plan made by him, as a commercial city, with its chief movements from river to river; but experience has not confirmed this theory, and the system of blocks is reversed from what it should be, for up and down town travel. As the streets lie across the lines of movement, there is great inconvenience from the limited number of channels, and from the continued interruption of those which do exist, at short intervals, by the street crossings, and New York now has crowded avenues, and expensive projects for increased facilities in northerly and southerly travel.

Want of forethought in this matter is a fruitful source of expense in street widenings and openings, and the tendency of prominent centers to connect themselves by straight lines, often diagonal to intervening systems, is well understood in city experience. In the earlier days of city life, lines may be considered radical in size or direction, which prove, in time, wise preventives to legislation and costly rearrangement.

It is also to be observed, that in the vicinity of a great commercial city like New York, water fronts become valuable for business, for landings, ferries, and otherwise, and where it can conveniently be done, there is an advantage in making the street system deliver towards them.

* * * * *

While the New Utrecht system adopts that of South Brooklyn, in carrying the streets easterly and westerly, to and from the Harbor, in the other towns the general system carries the streets from the vicinity of the City of Brooklyn to the ocean, or its bays, in a northerly and southerly direction. Under this theory of future travel for this district, a street was located from a point near Greenwood Cemetery to the Atlantic, which became the directrix for the streets easterly, and was called West streets, its line being parallel with the Ocean Parkway and the central part of Coney Island Avenue. A part of Gravesend is laid out west of West street with similar plan of streets, crossing Coney Island to the Atlantic.

In Flatlands this plan is modified on the necks, to adapt the streets to their natural drainage lines and water fronts. To accommodate this arrangement, Flatlands avenue was located from Avenue P at a point near the Gravesend Town Line to the New Lots line, the streets being established, as a rule, at right angles to it, as far east as Fresh Creek Valley.

"With some local exceptions controlled by existing improvements, a study of the plans adopted for these towns will show a broad, comprehensive and uniform system of streets running towards the ocean or the harbor, carefully connected with the city streets and avenues, and located without regard to farm lines or individual interests, so as to meet and develop the interest of the dense population destined in time to occupy this area; an area with which no other, within the same distance from New York, can be compared in advantages for suburban life."

The question of street and block dimensions is important, and in this case was carefully considered. As a rule, the width of blocks is 200 feet, provision being made in certain cases for a width of 250 feet, intending to appropriate the central 50 feet for future rapid transit. The minimum and common width of streets is 60 feet, avenues 80 feet, with occasional widths of 100 feet. Parkways are occasionally provided 120 to 130 feet wide, and arranged for two carriage ways of 30 to 35 feet each, with a central promenade of 24 feet. The length of blocks is 700 to 800 feet. Under the authority given, the streets have ten per cent. of width of each side appropriated to court yards.

The method of measurement adopted for this survey was in some respects novel and of professional interest. After discussing the objections which obtain against surface measurement for accurate work, and are avoided by triangulations, and the delicate character of the coast survey base-lines, and the methods adopted by other engineers for similar work, the superintendent says:

"In this case, however, the distances for each block, and system of blocks, had to be actually determined on the ground, over this whole area of $36\frac{3}{10}$ square miles, involving a proximate length of street lines of nearly 2,000 miles; and it had to be done rapidly, with assistants under restricted pay, and in the simplest manner possible, with the ordinary field instruments, the Commission not feeling authorized to provide those of a higher class, or of any class.

* * * * *

"The attempt, in the varying changes of the day, to determine the temperature of a metal bar, laid on the ground, with a thermometer disconnected from it, as to accuracy of register for the bar, and multiplicity of notes and calculations, I wished to avoid; I also wished to obviate the multiplicity of level sights and corrections, and their chances of error; and also, the multiplied transfer stakes, for 50 feet lengths. Knowing that soft, clear, seasoned pine was much less affected by change of temperature, than any metal, easy to construct, transport, and handle, I concluded to make a trial of it for our bases.

"On this theory I arranged an apparatus consisting of a tripod about 7 feet long, carrying on a convenient drum about 600 feet of No. 13 annealed steel wire, and fitted with stay chains and a stout iron pin, to be driven in the ground and keep the tripod in place, when in use; also, a back stay rod, of the same length, driven in the ground, on line, supported by side stay chains and pins; between these the wire was stretched and supported at intervals of about 75 feet by ordinary wooden flags, fitted with sliding rests and keys, so that when the wire was secured behind the back stay pin, to a pin firmly driven in the ground, it could readily be brought to a level; or if the ground did not so permit, to a uniform inclination, for a distance of 500 feet or more, over the sliding rests of the back stay rod and the flags, and certain intermediate rests on the back led of the tripod. With a little practice this operation was rapidly and accurately made, the several flags, rod, etc., being first put in line on the main base, so that the wire near the back stay was plumbed from a plumb-clamp over the stake and tack, which was the starting (or intermediate) point of measurement. The wire being in line, under a tension of about 300 pounds, a pine rod $12\frac{1}{2}$ feet long, by standard, with brass butts carefully faced, was held under the wire with one end in contact with the face of the plumb-clamp, and a brass clamp properly faced and sliding on the wire, was put in contact with the other end and fastened by a hand-screw. A second sliding clamp was then put in contact with first and fastened, the rod being relieved. This clamp then formed the starting point for another measurement of the rod on the wire, being relieved and brought up to the forward clamp and reset as the measurement progressed.

"We had then an apparatus light, simple, easily transported, not easily injured, which three assistants could work in the field; a common spirit level sufficed for the wire in most cases, and in others the notes were so taken that levels on the several stakes gave data for corrections. The bases therefore did not require highly educated men, and the assistants were relieved from multiplied notes and calculations. Test benches of 500 feet were established, and the rod, in this way, frequently tested, and particularly after a wet interval, as it was soon ascertained that moisture was by far the chief source of any expansion.

"In the more delicate processes of the Coast Survey, etc., temperature sometimes becomes a limit to work; in one scientific description 100° is made the limit; but our work had to go on in the hottest and sometimes in the coldest weather. Under these conditions, I consider this system of measurement the key to the successful completion of our work in time, cost, and correctness.

"The same rods were used from July, 1871, throughout the field work. Theoretically, the effect of changes in temperature, taking the modulous of steel, as adopted by the Coast Survey, at 0′.0000064 for 1° Faht., and of pine (or deal) by Joul, at 0′.0000023, would be on 100° range for 5,000 feet 3.20 feet in one case, and 1.15 feet in the other; practically, we found the changes of the rods slight, as a rule, in different seasons. For instance, Rod No. 1, on 500 feet test, January 9th to 31st, 1872, stood 0′.022 short (for whole distance); February 7th, 0′.0165; April 12th, 0′.023 long; May 8th, 0′.029 long. Rod No. 2, in August, September and October, 1873, ranged from 0′.010 to 0′.020 long on various intermediate tests. In July, 1871, a moisture test showed an expansion for a wet rod of 0′.500 in 5,000 feet; but as no measurements were made with a wet rod, our chief care was to detect the effects of absorption, which rapidly dried out.

"In New Utrecht, 60th Street was located parallel with 58th Street, and made the base of the adopted system, and 86th Street was established parallel with it, by measurements on 9th and 22d Avenues, this parallelogram being the basis of included or extended bases from West Street to 4th Avenue. In making the check measurement down 14th Avenue base, from 60th to 86th, the error was 0′.04, on a distance of 6,940 feet; and the diagonal base measured down 4th Avenue, also checked and proved the transit line. On part of the Ocean Avenue base line, a check measurement over a distance of 12,410 feet, by standard, came out 12,409.90. On all the main parallelograms, the measurements and transit checks were satisfactory, except in one case in Flatbush, which occurred through checks improperly reported, but was not deemed of sufficient consequence to alter, after the monuments were set, and is corrected on the maps, for main angles.

"In transit work, by using glass diaphragms in the instrument for intersection, which are much less subject to temperature and moisture changes than spider-lines or platina wire, and by care in multiplying or reversing sights, the work, in the hands of skillful assistants, proved very satisfactory, under severe tests, though carried on through all seasons, and with ordinary engineer transits."

As a practical comment on the value of this survey, it may be said that during its progress about 50 miles of streets and avenues have been completed, or are now in progress within the towns. Very favorable progress has also been made in the preliminary work of a steam railway intersecting them all, and running from a ferry landing at Bay Ridge, from New York, to a junction with the Canarsie, Long Island, and other railroads in Queens County. Other projects are also under discussion to provide for the large annual surplus of New York a cheap and convenient suburban development in this section; and it is hoped that the next ten years of its history will show a progress more in keeping with the results in every other direction from the great city.

It is announced that a very rich bed of nickel has been recently discovered in the forest of Glorud, in Norway. The ore proves to contain 3.59 per cent. of pure metal; an exceptionally large proportion.

Some experiments are being made in France on some iron ore which has been brought from Algeria. It is said that steel can be produced from this which is superior to any other for the manufacture of cannon.

IMPROVEMENTS IN BLAST FURNACES—THE CLOSED HEARTH SYSTEM.

From the "London Mining Journal."

The closed hearth invented by Mr. Lürmann, and referred to in the *Mining Journal* some time since, appears to have given great satisfaction wherever it has been applied. It is well known that as a rule, a much larger proportion of slag than iron is produced ; it is, therefore, a necessity for the metallurgist to get rid of the slag till a sufficient quantity of iron has been gathered at the bottom to have it tapped, which is generally done at certain intervals—say every 12 hours. To effect this discharge of the slag, it has been usual to construct the hearth with a so-called open forepart. This consists in the widening of the hearth in the front from 4 to 5 ft. in length, 2 to 3 ft. in width, and 2 to 3 ft. in height, being closed in the front by the dam. The lowest part of the top of this opening, protected by a tymp-plate, is generally 10 to 18 in. below the level of the top of the dam. The slag, to leave the furnace, has to travel underneath the tymp along the forepart over the dam, so that either it has to stand at a higher level in the hearth than the top of the dam, or—this is usually the case—the pressure of the blast effects the discharge of the slag.

This system was long acknowledged to have many disadvantages, and it was long felt that if the open forepart could be done away with they would disappear; in fact, the first blast-furnaces were without forepart, and have been and are known in Germany and Austria under the name of "Blauöfen." The hearth is made circular, and has a tapping-hole, two tuyeres, and a slagging-hole, consisting of a slit in the wall stopped with clay. When the slag has to be run off a hole is made in the clay of this slit, through which the periodical, not continuous, discharge takes place. A more primitive method, still in use in Styria, is to run off the slag, together with the iron, through the tapping-hole. This simple procedure, however, is only possible where the ore is very rich, easily fusible, and where the fuel consists of charcoal, where consequently but little slag is produced. These furnaces work with closed hearths. The labor at such furnaces being minimised, it has often been tried to adopt this system to coke blast-furnaces, but for a long time without avail. The slag of such furnaces is hotter, and dissolves the clay. When, therefore, the Blauöfen system was tried at the coke blast-furnaces, the hole in the clay through which the slag ran though originally small became soon larger and larger, much blast was lost and the fuel thrown through the so created opening. To stop the hole the blast had to be taken off, which occurred, however, so often that the ordinary plan was found to be more profitable. Still, eminent metallurgists—among others Prof. Tunner, of Vienna—considered the open forepart system imperfect, and strongly desired and advocated the adaptation of the closed hearth system to coke blast-furnaces. Mr. Lürmann when he found that slag would run through a block cooled by water had discovered the means to do away with the forepart. He applied his plan to a furnace in blast, and obtained results so good that all the furnaces at Georgs Marien Hütte, near Osnabrück, where he was then managing director, were altered accordingly. His system was soon adopted at most of the best ironworks in Germany, and later in the United States of America. It was also introduced in Austria, Belgium, France, and England ; and he has since done much toward perfecting his invention. The hearth is entirely circular, there is no tymp, forepart, or dam. The blast tuyeres are 42 in. or more above the bottom of the hearth, and equally distributed all round. Between two of the tuyere-houses there is an opening for the slag discharge 32 in. high and 20 in. wide, covered in by cast-iron plates. In this opening a water-cooled casting is placed, of which the back part is flush with the inner side of the furnace. This casting is smaller than the opening, to facilitate an exchange; the space left between the casting and the wall is filled with fire-clay and fire-bricks. Into this casting the scoria block is fixed, which is a block of metal, cooled by water, with a hole for the slag to run through. It may be made of any metal, cast or wrought iron, but preferably of bronze. The bronze scoria blocks last much longer than the cast or wrought iron ones, and need not, therefore, be exchanged so often. They are also cheaper in the end, as old cast or wrought iron scoria blocks are nearly valueless, whilst those of bronze fetch more than half their original price. The scoria blocks have wrought-iron pipes of 1 in. bore screwed into them for the inlet and outlet of water. The slag-hole has from 1 to $1\frac{1}{2}$ in. in diameter; the size depends entirely on the quantity and consistency of the slag produced. It should be so chosen that as much slag is discharged as is made. The centre of the whole is from 12 to 16 in. below that of the tuyeres; the blast will, therefore, not be obstructed by the slag. The block is held in its position by a key to the casting; if the block has to be exchanged the key is taken out, and a bar with a nose put through the reserve opening. The scoria block, against the back of which the nose of the bar is made to rest, is then easily pulled out. The tapping-hole is placed wherever most convenient in the circumference of the hearth, the slag and iron need not, therefore, be run off on the same side, as is necessary at furnace with open foreparts.

In working furnaces on this system. It is not necessary when about to tap to stop the scoria-hole, as the slag will cease flowing as soon as the iron runs out of the tapping-hole. When the cast is completed, the tapping-hole has to be closed in the usual way ; this is the only time when the blast must be taken off, except in case of accidents. At the same time the scoria block is cleansed from the scoria crust, then stopped first with sand, and afterwards with a little clay. These operations will be finished in three or four minutes ; the blast is now turned on full. To prevent a thick crust forming behind the scoria block, only very little water should now run through it. As soon as the slag is observed at the tuyeres, the hole of the block has to be opened, which may be done with a wire rod, if the furnace work well, otherwise a blunt bar, a little less in diameter than the hole, must be driven through it some distance into the hearth, and then quickly pulled back. The slag will follow in a stream of the size of the hole.

As soon as the slag begins to run through the block the water must be so far turned on as to leave the block lukewarm. If the proper size of the hole of the scoria block, according to the quantity and quality of slag produced has been chosen, the slag will run interruptedly till next tapping time. For a large coke blast-furnace, with good hot thin slag, a hole of $1\frac{1}{4}$ in. has been found sufficient. Should blast blow through the hole continuously it is a sign that it is too large, and a block with a smaller hole should be put in. If temporarily less slag is made it suffices to put a bar tipped in clay into the hole, when this slag will cease to run. As soon as there is sufficient on again the bar is withdrawn. It is best to tap after a certain number of charges have been put into the furnace ; the number is regulated by the quantity of slag run out through the tapping-hole at the casting time. For it is evident that this slag occupied the space between the scoria outlet and the top of fluid iron ; it should be about 10 cubic feet, to prevent the iron from touching the scoria block. If, now, the above quantity be more or less than the 10 cubic feet, the number of charges should be altered accordingly. In case the furnace should work badly, the slag will generally run through the block easily, as one end of the latter extends into the hearth, whilst the slag would not do so had it to travel the long distance underneath the tymp along over the forepart over the dam. Should the furnace work so badly that the slag will not run even through the hole of the scoria block, the reserve opening must be used. The slag will always freely run through this opening which is considerably larger than the hole of the block. After a bogieful or two have run through this opening the crust behind the hole, which blocked the discharge of the slag through the scoria block, will have melted away. The opening may then be stopped, and the scoria block hole opened.

It has been said to be a great disadvantage of this system that if the furnace works so badly that the hearth grows up there would be no means to work with bars inside the hearth ; but the simple answer to this is that the bar working in such cases is of little avail, and that the proper remedy would be to alter the burdens. The closed hearth gives a better chance for the furnace to come round again than the open forepart system, as the heat is better kept together.

THE VENTILATION OF THE CHANNEL TUNNEL.

From the "Engineer."

While we hold that the construction of a railway tunnel between England and France by private enterprise would prove a disastrous speculation for the original shareholders, we are by no means supposed to deprecate the carrying out of the work by the Governments of France and England, or, which comes to nearly the same thing, by public companies to whom a certain interest—say, four per cent.—would be guaranteed by the two nations. We shall not stop to consider the precise nature of the results which would accrue from the formation of the tunnel. It will suffice for the present if we admit that there is no reason why it should not be made under the conditions which we have laid down; and if we admit that the work may be carried out, the details of its construction and operation become legitimate subjects for discussion in these pages. The details of construction will probably be elaborated only as the boring proceeds ; and it is also probable that they will not differ much from those of the St. Gotthard Tunnel. We shall have perforators propelled by compressed air, and rails to carry the *debris* to each end. Furthermore, the tunnel will be either double or single, and lined with brick in cement from end to end. Two lines of rails will be laid. Less would not suffice, and it is improbable that more will be attempted. We shall have then a tunnel which will be at least twenty miles long from end to end, without counting land lengths of tunnel on the coasts of England and France. This tunnel will fall towards the middle and rise towards each end, and so far as tractive power for the propulsion of trains is concerned, it may be regarded as a dead level, the inclines compensating each other. Up to this point there is hardly any difference of opinion about the structure. Most if not all engineers will agree that we have sketched roughly but accurately the future road under the Straits of Dover. But arrived at this point, chaos presents itself. No one has expressed a well considered opinion in public as to how the trains are to be propelled, or the ventilation of the tunnel is to be effected. So far as we can see the general expression of sentiment on the subject is: "Let us have the tunnel, and we shall easily work it and ventilate it." Now it appears to us that the ventilation of a tunnel twenty miles from air shaft to air shaft, and placed deep down below the sea, is a matter which cannot thus lightly be disposed off ; on the contrary, the problem is one of unexampled difficulty, and of the greatest possible importance, for on it hangs the whole future of the gigantic scheme.

Let us assume that it is fixed that the rate of traveling through the tunnel shall be forty miles an hour; then half an hour will be occupied by each train in going through. The line will, of course, be worked on the block system, that is to say, no train will be permitted to enter at the Dover end until the previous train has come out at the Calais end, or *vice versa.* This would allow forty-six trains a day each way, an hour being reserved during which no trains would run, in order that repairs might be carried out. This is the maximum possible number of trains without an intermediate block ; but for obvious reasons it would not be safe to count on this number, and thirty-six trains in twenty-four hours are as many in all probability as could be run. If no greater number passed through the tunnel, it is clear that no dividend could possibly be paid unless the tariff were so high as to be prohibitive. We shall not stop to ask whether more demands will arise at any reasonable tariff than thirty-six trains a day each way would satisfy. If more trains are to be run, then a block station must be made about the middle of the tunnel, and we do not envy the lives which signalmen at this station would enjoy. It is not necessary here to go into any calculations as to the power required to propel the trains through the tunnel. Let us suppose, for the moment, that it will be worked by ordinary locomotives with 17 in. cylinders, 24 in. stroke, and four-coupled drivers 6 ft. diameter, the goods engines being almost identical, except that they would have six-coupled wheels 4 ft. 6 in. diameter. The consumption of coke by the passenger engines would be about 30 lb. per mile; the goods engines would probably burn 45 lb. Let us take the average consumption all round at 35 lb. of coke per mile; this represents, at the least, $24+35=840$ lb. of air ruined for the purpose of supporting life or combustion per mile per train; or, in other words, about 320 cubic feet of air per pound of fuel, or 11,200 cubic feet per mile run. But apart from this, each pound of coke burned represents $3\frac{2}{3}$ lb. of carbonic acid. That is to say, we should have per mile per train 127 lb., or about 520 cubic feet, of carbonic acid gas discharged into the tunnel. The open air contains a variable volume of carbonic acid amounting on the average to from three to six parts in 10,000. When the proportion increases to twelve or fourteen parts in 10,000, as in crowded theatres, the atmosphere becomes exceedingly unwholesome. If fifteen or eighteen parts of carbonic acid in 10,000 were found in the air of the Channel Tunnel, passengers would suffer seriously. To bring up the proportion to this point, however, it is only necessary that the engines should give off carbonic acid gas in the proportion of twelve parts in 10,000, the other three or six parts already existing in the atmosphere outside. Now the cross section of the double tunnel will be about 500 square feet, and the cubic contents per mile will be 2,640,000 cubic feet; the engines will each discharge, as we have seen, 520 cubic feet per mile, which would suffice to raise the proportion by about $\frac{2}{10000}$. Three trains would suffice to bring the carbonic acid to the highest limit consistent with comfort if no ventilation took place. But counting the double service, seventy-two trains would pass through the tunnel in twenty-four hours, or three trains per hour, from which it will be seen, that to secure proper ventilation the entire contents of the tunnel should be renewed every hour. But the tunnel is twenty miles long, and as all the air must be withdrawn from either one end or the other, this would mean that a current of air moving at the rate of twenty miles an hour would have to be passed through the tunnel, which is, for obvious reasons, impossible. If we were content to let the condition of the air become very bad, it would be possible to get on, perhaps, by changing the air at half the preceding rate, but even then the velocity of the current would be ten miles an hour.

No doubt these figures appear startling, and we shall be asked how it is possible to carry on the traffic of the Metropolitan Railway, which is not traversed by a current moving at ten miles an hour? The answer is that there are dozens of ventilating openings in the Metropolitan tunnels, and that the distance between the stations where the ventilators are very large is extremely moderate. Thus, to change all the air within an hour in a piece of tunnel one mile long, it is obvious that the current needs to move at but one mile an hour, because a cubic foot of air entering at one end would at that velocity escape at the other after the lapse of an hour. But in the case of the Channel Tunnel it will be seen that every cubic foot of fresh air which entered, say, at Calais would, in the course of one hour, be supplied with $\frac{6}{10000}$ of carbonic acid, at which time it ought to be discharged; but it cannot be discharged till it reaches Dover, and it ought, therefore, to travel at twenty miles an hour. The practical effect of ventilation in this way would be that, while the air at the influx end would be pure, that at the efflux end might contain $\frac{12}{10000}$ of carbonic acid. It may be argued that the Mont Cennis Tunnel, eight miles long, is satisfactorily ventilated: but the cases are not analogous. Comparatively few trains pass through the Mont Cenis in the day; three in the hour would, as we have seen, require a current of but eight miles in sixty minutes. As it is, the ventilation is excessively bad, although from the great altitude of the tunnel above the level of the sea, strong winds play about the end of the tunnel, and no doubt powerfully promote the passage of air through it. As regards the Channel Tunnel, no such condition exists; it could not be worse situated for natural ventilation. We do not assert that it is impossible to produce a current at the rate of ten miles an hour through it by furnaces or fans; but we do assert that the cost of keeping either fan or furnace going, which has to get rid of some 25 millions of cubic feet of air per hour, will form no inconsiderable item in the working expenses. Indeed, the difficulties which stand in the way of ventilation are so great that it will, in our opinion, be out of the question to use locomotives burning either coal or coke, and the propulsion of the trains must be obtained in some other way. It would be impossible, however, to discuss properly the possibilities of Channel Tunnel propulsion within the limits at our disposal just now. We shall return to the subject. Our purpose at present is to prove by a few figures that it is, to say the least, unwise to assume that the ventilation of the tunnel can be left to take care of itself. Unless the atmosphere is pronounced pure and wholesome, the tunnel will never enjoy favor with a travelling public, and nothing connected with the tunnel would prove more reassuring than the supply of ample evidence that its projectors are prepared with a well-digested scheme for sending plenty of fresh air into it. On this point, however, as we have stated, a somewhat ominous silence prevails at both sides of the "silver streak." It is perhaps time that this silence was broken.

NEW METHODS IN TOPOGRAPHICAL SURVEYING.

By Prof. A. S. HARDY.

Written for Van Nostrand's Magazine.

While in Paris during the winter of 1874, the attention of the writer was called to the extensive application of photography to topographical engineering, as practised by the French engineers. This fact was pointed out in the Reports of the U. S. Commissioners to the Paris Exposition of 1867,* with a brief description of the principle under which the process was conducted, but so far as the writer is aware of, the method has received no practical application in this country, nor the attention which is its due. The value of topographical maps, especially in railroad surveys, is too well known to be insisted upon, and the aid they have rendered in France especially is very notable. Any process by which the time, and thus expense, of a topographical survey may be reduced, has therefore a peculiar value in this country where the magnitude of the work has proved, as it were, a dead weight to any extended project of this nature. The photographic process, for example, would be invaluable in the projected survey of the State of Massachusetts, and will amply repay the brief study which its novelty demands. It has long been the practice in hydrographic and topographical surveys to make sketches of the shores or landscapes, on which are written, near prominent points, their angular distances measured by an instrument. This was extensively practised in the hydrographic surveys of the West coast of France, and notably also in the surveys made during the voyage of the "Bonite." In the report of the Abyssinian Commission made to the *Académie des Sciences* in 1846, M. Arago urged the adoption of panoramic views, with the angular distances between prominent points (one of which should be exactly located), inscribed thereon, as a prevention against errors and a precious source of reference for all time. Even as far back as 1802, a Commission had been appointed by the French War Department

* Vol. V. Report on Photographic Apparatus, p. 11.

to study this subject, and its report* contains the following remark: "The Commission believes it always useful and often necessary, in topography, as in the other arts, to add to the horizontal projection or plan which constitutes the map, a vertical projection or perspective, and desires that when possible this may never be neglected, even when at the time its utility is not apparent."

The first systematic study of this subject was made by M. Laussedat of the Engineers. For this purpose, he employed, in 1854, Wollastin's Camera Lucida, under a slightly modified form to avoid parallax. Subsequently, in 1861-2, this study was extended to the Camera Obscura. With the assistance of Capt. Ducrot and others, M. Laussedat used the process to be described in numerous extended surveys, and it is to the courtesy of the latter, now Colonel of Engineers, that the writer is indebted for many details which are the fruit of experience alone.

As evidencing the economy of this method in time, reference may be made to the work done in Savoy and the Vosges. In the former department, one survey of 18 days field work sufficed for 30,000 acres, contour lines being mapped 5 meters apart, giving 5 months' office work. In another case, 110 proofs were taken for 20,000 acres, the field work consuming but 15 days. These examples are taken at random from among many instances to show the relative time required by this and the usual method. This will depend somewhat, of course, upon the character of the country, but M. Laussedat has not found that it requires more than one-third that by the ordinary triangulative and often less. In the field work alone the economy is very apparent. The instrument employed is a combination of the camera and theodolite. The camera proper carries on its front face the usual objective, mounted in a sliding tube, so that the focal plane may be made coincidental with the sensitive plate at the rear of the chamber, and this tube is provided with the usual diaphragm to insure the distinctness of the images. A cover similar to that of the telescope excludes the light, but should slide easily on the objective without disturbing the instrument when leveled. Once focussed, the position of the tube may be marked, as it will not be necessary in landscape views to readjust it, as for near and distant objects. The grooves in which the slide containing the sensitive plate moves should be constructed with care, so that the latter may exactly occupy the focal plane. Within the chamber are placed four fine needles, one in the middle of each side near the slide, destined to intercept the light, thus marking on the proofs four points, which joined, give a horizontal and vertical line through the center of the field of view, whose use will be shortly noticed.

The chamber is supported in the usual way by two cylinders, one solid and fixed to a tripod with leveling screws, the other, hollow and enclosing it, is fixed to the chamber. The chamber may thus be revolved about the vertical axis with the hollow cylinder which carries a vernier reaching a graduated limb fixed to the inner axis. An 8-inch limb with a minute reaching vernier is sufficiently accurate for all operations which are to be graphically reprinted.

On one side of the chamber is a telescope and level. This telescope has a motion about a horizontal axis, and carries in its revolution a vernier reaching a vertical limb fixed to the side of the chamber. The plate on which this arc is engraved is one piece with the axis, which projects simply far enough to permit the vertical motion of the telescope. This apparatus, as well as the objective, may be dismounted for packing in a separate box as usual, and a counterpoise on the opposite side of the chamber insures stability when mounted. The adjustments of this instrument are obvious:

1st. The axis of rotation of the telescope must be vertical. In the instrument seen by the writer there were but three leveling screws, and the horizontal limb was so constructed that when the zeros of both verniers were at the zeros of their respective limbs, the level was parallel to a line, joining two of the screws. The adjustment was then readily made with the leveling screws and tangent screw to the telescope. This construction, common to French instruments, is of course unessential.

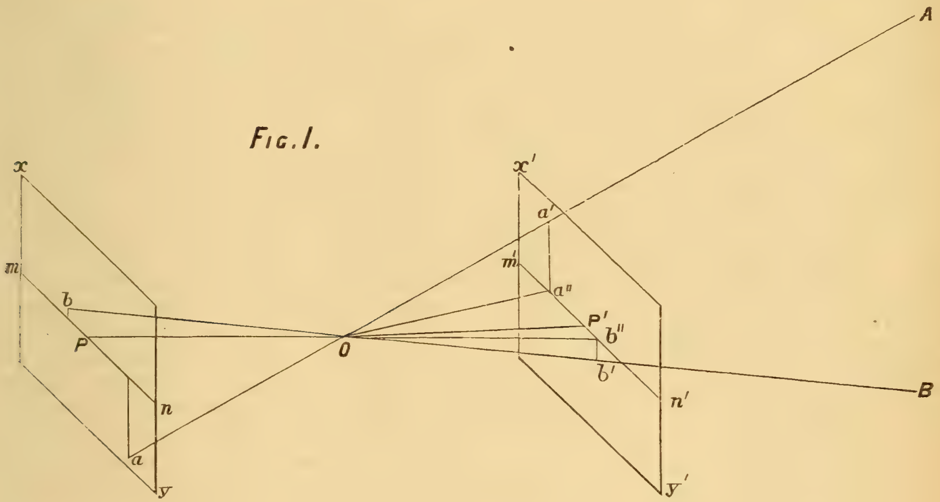
* Mémorial du Dépôt de la Guerre. Vol. II. p. 11.

2d. The line of collimation of the telescope, which is provided with both cross and stadia hairs, is effected as usual.

3d. The optic axis is made horizontal as in the ordinary geodesic instruments, and the reading of the vernier after adjustment is the error of collimation, to be added or subtracted, according to its sign, to the vertical angles subsequently taken. Two important conditions must be fulfilled by the maker: (*a*) When leveled, the axis of the telescope and the optic axis must be at the same height and thus describe one and the same horizontal plane during the chamber's revolutions; (*b*) The slide at the rear of the chamber, when in position, should be vertical and perpendicular to those axes.

It is thus seen that the instrument differ from those ordinarily in use only in a few details dependant upon their combination, and its use requires a knowledge of only the simplest principles of scenographic projection. Indeed, the proofs are themselves conical projections, the optic centre of the line, which is the vertex of the cone, being the point of sight, and, as in landscape views, the objects represented are so far distant as to have their images formed on the same focal plane, the distance of the point of sight remains constant.

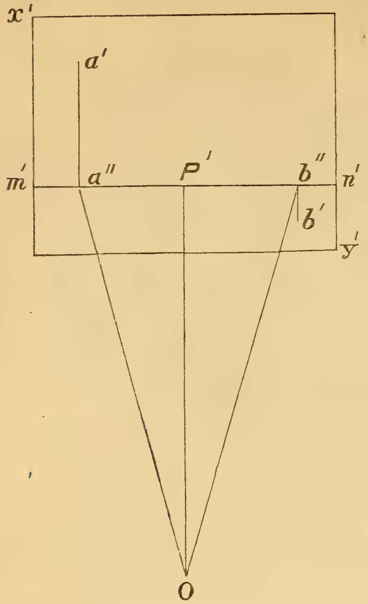
FIG. I.



Thus let *O* be the optic center of the objective, its axis *O P* being horizontal, and *x y* the glass slide at the rear of the camera, occupying the focal plane. Then *O* is the point of sight, *P* the principal point, m n the horizon, and any two objects as A and B will appear at a and b. If a glass *x' y'* were placed between the objective and the landscape, and at a distance from *O* equal to *O P*, the representation would be similar to that on *x y*, and will in part correspond to a *positive* proof.

If the perpendiculars be let fall from *a'* and *b'* upon the horizon *m'n'*, and their feet joined with *O*, then will *oa''* and *ob''* be the projections on the plane of the horizon of the visual rays *OA* and *OB*, the angle *a''ob''* will be the angular distance between *A* and *B* reduced to the horizon, while the angles *a'oa''* and *b'ob''* are the angles of elevation or depression of objects above and below the horizon. All points of the landscape at the same level as *O* will appear on the horizon, the curvature of the earth, unimportant in such operations, being neglected. The proof is thus a conical projection whose point of sight is the center of admission of the lens, and the distance of the point of sight from the plane of the picture is the principal focal distance.

FIG. 2.

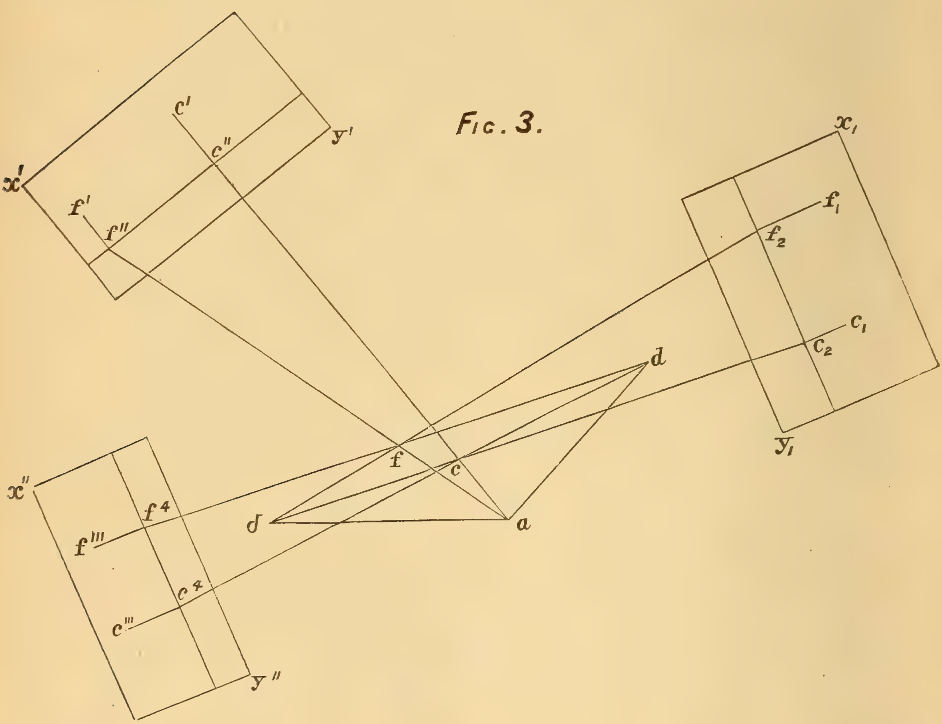


If then $x'y'$ be a photographic view on which the position of the principal point P' and the horizon $m'n'$ is known, as well as the principal focal distance of the lens, let the plane of the horizon be revolved about $m'n'$ until coincident with the plane of the picture. O will be found at a distance from $m'n'$ = principal focal, and is the revolved position of the point of sight. Join the foot of the perpendiculars $a'a''$ and $b'b''$ with O, then $a'ob''$ will be the horizontal angle between the objects having a' and b' for their images, *i. e.* the angle usually measured in the field. Finally, the vertical angle of any object as that whose image is a', is obtained by the ratio $\frac{a'o''}{oa''}$, its trigonometrical tangent.

Both the vertical and horizontal angles are thus determined from the vicus.

Suppose, now, a base line ab measured in the field, as also two angles $c\,b\,a$ and $c\,a\,b$ on any prominent object as c, and

FIG. 3.



that $a\,b\,c$ be the plot to any convenient scale. Having two angles and a side, the distances $a\,c$ and $b\,c$ may be computed. Suppose also two views $x'\,y' + x_1\,y$, taking one from a and one from b, and both containing the object c at c' and c, respectively. Having let fall the perpendiculars $c'\,c'$ and $c_1\,c_2$, let the proofs be revolved about their horizons into the plane of the picture, and the points of sight placed at a and b respectively. Join c'' with a and c_2 with b, and revolve each wire about a and b respectively till $c''a$ and c_2b pass through the point c previously determined. In this position any object on both views may be located on the plan. Thus, one whose images are f' and f_1 will be found at f, the intersection of two lines af'' and bf_2 drawn from the points of sight to the foot of the perpendiculars $f'f''$ and f_1f_2. It is thus evident that a great number of points may be determined without further direct measurement. The plot is verified as usual in the method of intersections. A third view $x''\ y''$, taken at any point as d and containing the object c, is placed in position as before so that the line dc_4 passes through c. A line joining d and f_4, should pass through f. Once verified in this manner, all views containing objects thus fixed can be placed in position. M. Laussedat, however, finds it preferable to measure each base, and to take either one or two angles to fix the position of each proof. Usually the angles between the bases and the angle between the base and principle point are measured. All other objects which are to be represented on the plot are located from the proofs.

To determine the height, of f'' for example, suppose the focal distance $1^{ft}.5$, and let $af''=1^{ft}.55$ $f''f'=0^{ft}.05$, and and $af=0^{ft}.55$, and the scale be $\frac{1}{8000}$. Since $f'f''$ is the apparent height of f' at the distance af'', and $af \times 8000$ its true distance, from the proportion

$$af'' : af \times 8000 :: f'f'' : x$$

we have

$$x = af \times 8000 \frac{f'f''}{af''} = .55 \times 8000 \frac{.05}{1.55} = 141^{ft}.9$$

Hence the height of any object above the extremity of a base is found by multiplying the tang. of the angle of elevation (to a radius equal to the distance of the station from the foot of the perpendicular through the object) by the true distance as found on the plot. To this product the height of the instrument must, of course, be added.

The heights are also verified by performing this operation with reference to two stations a and b, whose difference of line is known. It is not necessary that this difference be measured in the field, since any difference in line between two sections will be indicated on the proofs by a change in the position of the horizon, and may be therefrom determined.

This horizon is indicated on the picture by the shadows of the needles already mentioned as placed within the camera. These needles are adjusted by the maker, but are held in small pieces moving in grooves, so that their re-adjustment is always possible. To effect this, it is only to be remembered that when the instrument is in adjustment and revolved, the axes of the camera and telescope describe the horizon, so that if during this motion the intersection of the cross hairs be fixed on any object, its image on the glass slide will fix one point of the horizon, and by turning the instrument to the right and left till the object is brought to the edges of the slide, two points may be there marked, and the shadows of the needles should fall on the line which points them. The position of the needles giving a vertical through the centre may be verified on the positive proof. Except in case of accident this adjustment, if made by the maker, need not be repeated.

If, as is usual, the objective is fixed in the middle of the front of the camera, the horizon will divide the proof into two equal portions. M. Savary has modified this arrangement by making it movable in two vertical grooves, one of which is graduated to permit the measurement of the displacement. In very mountainous districts the position of the horizon on the proofs may thus be changed. When the point of sight is above objects whose images do not fall within the limits of the proof, the horizon should be lowered and *vice versa*. The line marked by the needles will then indicate a parallel to the horizon, which may be drawn parallel to this line and at a distance from it given by the graduation near the objective, whose zero of course corresponds to that position in which the horizon is given by the needles. As the image is reversed, when the objective is raised the horizon must be drawn below and *vice versa*. Ordinarily the views do not cover all the field, and this simple expedient permits the increase of the field of view in certain cases without increasing inconveniently the dimensions of the apparatus.

The distance of the point of sight from

the picture, *i. e.* the focal distance of the objective, may be found from the triangle $a'' P' O$ (a'' being any object on the horizon), by the formula

$$O P' = a'' P' \cot a'' O P'$$

$a'' P''$ being measured on the proof, and the angle $a'' O P'$ by the horizontal motion.

The question has probably already occurred to the reader, to what extent does spherical aberration prove a source of error in the use of the camera obscura? For objects distant from the centre of the field of view will not have their images formed *exactly* in the principal focal plane. The very able researches* of Col. Laussedat on this subject, published in 1864, show that in the clearest manner for all ordinary cases, where the apparent heights of objects above the horizon on the view are small, the vertical component of the angular deviation (which is the same in every direction, everything being symmetrical about the optic axis) may be neglected. So that except in rare cases the trigonometrical tangent, already given, is taken as the measure of vertical angles. The horizontal component, however, cannot be neglected. With a simple achromatic objective of 0m.081 diameter, and a focal distance of about 0m.5, and a diaphragm of 0m.015 opening, 0m.077 in front of the nearest lens surface, the focal distance was found to differ slightly with the position of the point a''. Thus for a point 0m.005 from the principal point, the focal distance was 0m.505, but for a point near the border of the field of view, 0m.1476 from the principal point it was 0m.500. That is the focal distance diminished as the point from which it was calculated receded from the principal point. Evidently, then, if in the construction of the plan the focal distance was used as found by a point near the centre, the error would increase as the instrument was turned, and in 360° would reach in the above case 4°. If, however, we use for focal distance that calculated from a point near the border of the field, the error does not multiply; near the principal point and borders it is altogether insignificant, and midway between is a maximum, where in the above case it would not depress 5 minutes.

* Mémorial de l'Officer du Genie, No. 17, p. 273.

Without corrections, therefore, an exactness is obtained by this precaution more than sufficient for graphic constructions.

After what has preceded, the following *résumé* will be clearly understood:

FIELD WORK.

This includes first the measurement of the bases and angles. The notes are kept in five columns in which are recorded: 1° the position of their stations; 2° the length of the bases; 3° their included angles; 4° an angle measured between the base and any point in the field of view, serving to fix the position of the views on the plan. (These may be the principal points.) 5° Remarks.

The base may be measured by the chain. With the 12½-inch telescope, seen by the writer, and adopted as a good size for a camera whose horizontal dimensions are 16″×18″, bases not excluding 1,000 feet may be measured to within less than $\frac{1}{200}$th by the stadia. The stations are best chosen on the borders of the survey on dominant points, but central ones may be necessary, and in an extensive survey are selected very much as in ordinary triangulation, those being the most advantageous which are sufficiently elevated to unmask more distant objects. Stations near together are to be avoided, as the bases are thus short as compared with the lines of intersection which fix the objects on the plan, and therefore intersect under an acute angle. Should this be unavoidable, a simple method of avoiding inaccuracy will be indicated in the description of the office work. The photographic operations do not need description here. It may, however, be said that the French engineers prefer the use of paper to glass, which is fragile and heavy in extended surveys. The positions thus obtained, though less distant usually than those obtained with glass, are sufficiently so.

Finally, in certain localities, as among buildings or in depressions, slight sketches will complete the details and obviate a multiplication of views.

OFFICE WORK.

Inasmuch as the focal distance is the scale of the views, it bears a relation to the scale of the plan. M. Laussedat states that experience has shown a focal distance of 0m.5 best adapted for scales between $\frac{1}{2000}$ and $\frac{1}{10000}$. The distance at which one may operate also depends upon the scale. Suppose the scale chosen is $\frac{1}{3000}$, then a focal distance of 0^m5 will represent on the plan 1,500 metres and points at a much greater distance from the station will not be obtained with the desirable precision. Were the scale $\frac{1}{8000}$ however, the operations could be conducted at 4,000 metres. The bases are just plotted with the protractor, and at each station is laid off the angles, taken from the notes, between the base and principal points of the several views. On each of these lines is laid off the focal distance, and at their extremities a perpendicular drawn, which is the trace of the plan of the picture.

A distant position serves for the determination of the focal distance. With this distance for a radius, the trigonometrical tangents of 1°, 2°, 3°....15° are calculated (a field of 30° giving the best results) and these distances are laid off each way from the centre of a horizontal line on a separate piece of paper. Through the points of division perpendiculars are then erected, and the descents of the same angles to the same radius computed, they being the length of the risual rays between any object and the point of sight, reduced to the horizon. Finally parallels are drawn to the horizon at equal distances apart. This diagram is then transferred to all the proofs taken with the same objective, taking care to make the coincidence between the horizontal line and the vertical through the centre, and the horizontal and vertical line through the principal point on the proof exact. Every point is thus referred to the horizon and vertical line, and the length of its visual ray reduced to the horizon is known.

To fix any point on the plan, its horizontal co-ordinates on two proofs are transferred by the dividers to the horizons on the plan, and their extremities joined with the proper points of sight. To determine the heights we have already deduced the formula

$$x = s\,d\frac{h}{d'} \quad \text{in which}$$

x = true height sought, h = apparent height $f'f''$ (Fig. III.), sd=true distance af, s being the denomination of the scale, and d'=the apparent distance af'', or the visual ray reduced to the horizon.

As in this formula d' is the secant exactly calculated and s is given, any error that may arise will be due to d and h, the former being measured on the plan, and the latter on the proof. Both of the errors due to d and h will then be multiplied by the fraction $\frac{s}{d'}$ and therefore are proportional to the scale and focal distance. Furthermore, any error in h, being multipled by d, will be greater as the object is further off. Views should then be taken as near as possible to objects where heights are desirable. For distances less than 550 yards the error will not exceed one foot with an objective of 1·64 focal distance. For extended surveys in which the contour lines are 10′, 15′, or more feet apart, all desirable accuracy is obtained with the above precaution, while, as already shown, an accuracy more than sufficient for graphic construction is obtained for the plan.

The office leveling notes are kept in eight columns as follows: In the 1° Designation of the points whose heights are sought.

2°. d'—the calculated descent or visual ray.

3° sd—the true distance taken from the plan.

4° $\mp h$—the apparent height, taken from the proof.

5° $\pm x$—the real height calculated from the formula.

6° The height above the plane of reference of the stations to which objects are referred.

7° Absolute height above plane of reference.

8° Remarks.

In operating upon bases small as compared with the visual rays, construct, on training paper, for each station a few horizontal angles for objects as distinct and far apart as possible, and fix these constructions on the plan as usual. Should the intersections not prove perfect, and if the angles have been carefully constructed, by very slightly moving the papers in succession, their position after a few trials may be completely rectified. The principal lines may then be marked lightly on the plot in pencil.

The leading operations and principles of the method have now been described.

Both M. M. Ducrot and Laussedat have compared at different times the results of this method with those obtained by an ordinary survey on the same ground, and found them remarkably exact, even on very difficult ground. The advantages of this application of photography are evident. No sketch can compare in completeness or exactness with photographic views, and by no other means yet known can the time and labor of a topographical survey be thus abridged. In proportion as the survey is small and the greatest possible accuracy requisite, this method loses its superiority. But for larger surveys, its advantages are unquestionable, and in all cases may be made a valuable source of contribution to those details which would otherwise demand a long and tedious direct observation, and the photographs constitute a series of notes good for all future reference. As briefly exposed in this paper, it is regarded as the last used on this subject by French engineers, and in view of the probable increase in topographical surveying in this country deserves the attention of our own.

APPLIANCES FOR ENABLING PERSONS TO BREATHE IN DENSE SMOKE OR POISONOUS VAPORS.

By CAPT. SHAW, Chief Officer of the Metropolitan Fire Department.

From the "Journal of the Society of Arts."

Numerous attempts have been made, both in ancient and modern times, to enable persons to enter safely into places full of smoke or noxious vapors, but very few of the appliances employed for the purpose, even though apparently successful during experiments, have received the sanction of permanent use. Means have been invented to enable persons to pass through the flames of a furnace at nearly white heat, but they have been troublesome and expensive, and obviously so seldom likely to be of any use except for purposes of display or public entertainment, that they have naturally fallen below the level of practical criticism, and are only mentioned here as matters of scientific curiosity.

Our great enemies in this way are smoke, and those innumerable poisonous vapors created by intense heat under certain combinations well known to chemists, but too abstruse to be explained here, which we designate under the general title of mephitic gases.

The vapors which we find dangerous probably include nitrogen, sulphuretted hydrogen, carbonic acid gas, choke damp, and numerous other defined and well-known gases, but it is unnecessary to enter here into the chemical details or to be very precise as to the terms by which these vapors are designated in laboratories, as I mean simply to include under the general head of mephetic gases, all those vapors we meet in our business which will not permit respiration to continue within their range.

To enable a man to enter into and remain in a place strongly impregnated with mephitic or noxious gases, two courses are open. One is to supply him with pure air from an external source; the other to provide him with the means of filtering for himself such air as he finds, admitting to his lungs only that which is pure and useful, and rejecting the rest.

I will now endeavor to describe a few of the best known appliances for this purpose, including long breathing tubes, air bags, and short tubes, smoke jackets, smoke cap, woolen filter, and fireproof clothing, and I will take them in the order here given, commencing with the long breathing tubes.

Long breathing tubes.—For supplying air from external sources several modes have been tried, among others what were known as breathing tubes, one leading from the external air into the mouth and nose, the other leading outward from the mouth and nose, with a mouthpiece and nose valve arranged for the purpose. This, in certain cases, has proved efficacious, but the working of it requires not only practice but an amount of attention which it is difficult to keep up, and when the inlet or air-pipe has to be very long, and to go round curves, the labor involved in breathing is sometimes considerable. Why this should be so I cannot say, as the pressure of the external atmosphere ought to be ample and more than ample to overcome the friction in the pipe; but it has occurred, and does occur, and therefore ought to be mentioned. Another application by these tubes, is by means of a mouthpiece alone, with two openings, which can be closed alternately by the tongue, the nose being stopped with a nose-pincers. This also has proved successful in very simple cases and for short periods, but it is evident that it would not do for our rough work and rapid movements. It is quite correct in principle, but is probably best adapted, in practice, to the purpose for which it has been much used abroad, namely, to enable persons to breathe under water in certain baths which require the immersion of the head. Attempts have also been made to work with a pipe leading merely from the man's mouth to the ground, but they have been unsuccessful, and when not unsuccessful have been useless, as a man generally is on his hands and knees on such occasions, and then does not require the pipe, or if he is standing up, he has only to stoop down and obtain such clear air as there may happen to be available.

Air Bags and Short Tubes.—Another mode is to carry into the smoky place an inflated bag of air, with two tubes of the kind already described connecting it with the mouth, one tube leading from the bottom of the bag or reservoir, and the other to the top, the tongue acting as a valve. In this case the man inhales through the tube leading from the bottom, and exhales through that leading into the top, and the discharged air being warmed, and consequently lighter, remains for a time on the top, and mixing with the remaining air, may be inhaled again several times. with such an apparatus working properly a man can remain in the foulest air several minutes, but it is obvious that he must be very careful in the management of the breathing tubes.

The Smoke Jacket.—One of the safest appliances for the supply of air to a person working in a smoky or vitiated atmosphere is that known for many years in most English fire brigades as the smoke jacket, and abroad as the *blouse contre l'asphyxie*, *appareil á feu de cave*, or in some places as the *appareil Paulin*, from the name of its supposed inventor. The smoke jacket consists of a blouse of cow-hide, pliable, light, and mounted with a hood, which completely envelopes the man's head. It is mounted in front of the face with a pair of eye-glasses, or a half cylindrical sheet of glass firmly fitted to the front of the hood so that the wearer can see every thing in the place to which he has penetrated; and underneath the mask there can be, if desired, a whistle fitted with a valve, which serves for giving signals. Straps and buckles, called bracelets, hold the sleeves round the wrists, and a thong, called a *cuissiere*, or leg-strap, which is fixed in front, and, after passing between the legs, is buckled behind, prevents the blouse rising. It is, besides, held over the hips with a leather girdle, on the front of which a lamp can be carried when required. On the left side is fixed a screw, to recieve the corresponding screw of a hose which is of the same pattern as those of the fire engines, and communicates at the other end with one of these engines. The pump of the fire engine being set to work, of course without water, drives air into the jacket, swells it out and keeps the man in a compressed atmosphere, which is continually renewed. The surrounding air cannot penetrate, being continually driven back by that escaping at the wrists and other openings. Once inflated the blouse holds enough air for a man to be able to breathe in it without difficulty for six or eight minutes, but it is necessary to continue working the pumps, in order to enable him to remain inside any length of time. When the lamp is lighted, air is introduced to it by means of a little pipe communicating with the inside of the jacket.

This smoke jacket is very useful for extinguishing fires in vaults, stopping conflagrations in the holds of ships, and penetrating wells, quarries, mines, and cesspools, &c.; any place, in short, where the air has become unfit for respiration. The special advantages of this jacket are its great simplicity, its facility for use, and the rapidity with which it can be carried about and put on; but its drawback is, that it requires the use of an engine, or air-pump, and consequently is of no service to one man alone. for this latter reason, smoke jackets, although very effective for enabling us to get into convenient places for extinguishing fires have very rarely proved of any avail for saving life.

Wherever vulcanized india-rubber tubes are used for the purpose of conveying air to the lungs, I should recommend very great caution, as it is undoubted that, at least in some cases, men have been known to suffer serious inconvenience, if not to incur considerable danger, from inhaling through this material. This is, however, a very trifling difficulty, and I have no doubt has only to be pointed out to be speedily obviated by improved construction.

The Smoke Cap.—Another apparatus, and one free from the disadvantage of being dependent on aid for its use, is the smoke cap, which is very light and portable, and can be brought into use in a few seconds by a man working alone.

A smoke cap is an apparatus by means of which a man is able to breathe when working in dense or poisonous vapors. It partially closes the nose, and provides for the mouth a light, closely-fitting filter with valves, and for the eyes a complete cover, which will act as a protection, without obstructing the sight, the whole being capable of being put on and completely adjusted for use in a few seconds by the man who is to wear it, without aid from any one else.

It is desirable that it should be strong and fit for rough work, also that it should contain no delicate parts likely to get out of order, and no material parts inaccessible for immediate examination.

Every one of these requirements may be separately carried out without much trouble, where the questions of time and rough usage can be put out of consideration; but the combination of the whole for rough work, and the shortness of the time available in our business for adjustment, have hitherto constituted very serious difficulties, which however, it may be hoped, are now, to a great extent, if not altogether, overcome.

The filter, which separates the pure air from smoke or noxious vapors, and which constitutes the specialty of the apparatus, is the invention of Professor Tyndall, who has in the kindest and most liberal manner placed it at our disposal, solely from public spirit, and without fee or reward of any kind whatever.

The first complete apparatus as now issued was designed and made up by ourselves in the workshops of the Fire Brigade, and served as the pattern for those afterwards furnished by contractors.

The smoke cap consists mainly of two parts, called respectively the hood and the respirator.

The hood is made of the best dressed calfskin blacked, cut in sections, and closed with air-tight joints, each part overlapping the next to an extent of half-an-inch, and the sections strongly sewn together with two separate rows of saddlers' stitching. The skull part is fitted to the shape of a man's head, and is about 24 in. in circumference at the widest part; underneath this there is a band about 2 in. deep forming a collar, to the lower edge of which there is attached a kind of yoke or apron-piece about 6 in. deep, shaped to fit on a man's chest and shoulders under a tunic.

To facilitate the putting on and taking off of the hood, there is an opening down the whole of the back part from the crown to the neck, and on each side a row of four eyelet holes with brass bushes, through which there is rove as a lacing a leather thong, the ends of which go round to the front, and after passing through a small metal ring, are knotted at the ends below two hard wood knobs, to prevent their being pulled back through the ring. When the hood has been put on, the thongs are pulled in front, and, rendering through the eyelet holes, draw the whole of the skull part close to the head. The opening at the back is fitted with a piece of what is commonly known as waterproof sheeting, a thin air-tight material which occupies very little space, and, although wide enough to allow the head to enter freely, is easily folded away by the drawing of the thongs. The lower flap or apron part is tucked in under the collar of a tunic, so as to form an air-tight joint sufficient for the purpose.

To the front of the hood inside is attached, by means of round-headed brass rivets, a frame or piece of tinned sheet metal, shaped to fit the front of a man's face from the bridge of the nose to the chin. Opposite the mouth there is attached to this frame a piece of brass, with a circular opening, cut on the inside with a female thread to take the male thread of a hard wood mouthpiece, and on the outside with a male thread to take the swivel screw of a respirator. The male screw to which this swivel is coupled has cut inside it a recess in which a leather washer is placed, so as to make an air-tight joint when the coupling is screwed up.

At a distance of about 4 in. above the mouthpiece there are fixed a pair of curved eye-glasses of the best clear glass, set with cement in brass rims with lugs, which are attached by screws to curved metal frames riveted on the inside of the hood.

The respirator consists of two parts, the valve chamber and the filter tube.

The valve chamber is formed of a piece of best drawn brass tube 2 in. long and 2 in. in diameter, with an upper and lower valve plate, and between the two a slotted horizontal opening to which is soldered on and riveted a brass connecting piece about $\frac{1}{2}$ in. long, fitted on the end with a swivel screw to match the outer mouthpiece screw on the hood.

Each of the valve plates is fitted with three ebonite ball valves, $\frac{1}{2}$ in. in diameter, turned perfectly round and without the slightest projection or rim in any part. The openings in the plates are $\frac{7}{16}$ in. in diameter, and are so cut that the seatings embrace at least one-third of the valves. The seatings, which are separate pieces screwed into the plates, and are most carefully beveled out so the valves shall make an exact fit, are neither so tight as to stick nor so loose as to allow leakage. The valves are properly protected above by metal guards, which allow a lift of $\frac{1}{8}$ in. for suction and a shade less for delivery.

Above the delivery valves there is screwed on a nut or cap plate, which protects the valves and guards from injury, and is pierced round the edge with 28 holes for the escape of the discharged air.

The filter tube is also of brass, of the same diameter as that used for the valve chamber, and is 4 in. long. Across the upper end inside there is soldered on a piece of fine copper wire gauze with $\frac{1}{16}$ in. mesh, to prevent wool or other light substances passing, and over the lower end there is screwed on a brass ring or cap with a similar piece of wire gauze.

The whole of the respirator is tinned inside and lacquered outside.

The following parts of the respirator are screwed on to each other, and are therefore capable of being quickly and easily separated for examination and cleaning when necessary:

1. The lower cap which has a female screw, and is joined to the male screw on the bottom end of the filter tube.

2. The whole of the filter tube, which has two male screws, the one at the bottom to take the cap, and the one at the top to join a female screw cut underneath in the cylindrical or outside part of the suction valve plate.

3. The suction valve plate, which has two female screws, the one at the bottom to take the top male screw of the filter tube, and the one at the top to join a male screw cut on the lower end of the valve-chamber tube.

4. The valve-chamber tube, which has two male screws, the one at the bottom to take the top female screw of the cylindrical part of the suction valve plate, and the one at the top to join the covering plate or top cap.

5. The top nut or cap plate, which has a female screw to receive the male screw at the upper end of the valve-chamber.

The charge for the filter consists of the following materials, which are put in with the tube turned upside down, and, of course, the lower cap removed:—Half-an-inch deep of dry cotton wool, an inch deep of the same wool saturated with glycerine, a thin layer of dry wool, half-an-inch deep of fragments of charcoal, half-an-inch deep of dry wool, half-an-inch deep of fragments of lime, and about an inch deep of dry wool.

These must be packed so closely as to fill every part of the chamber, and they should be pressed down as lightly as experience shows to be compatible with facility of breathing through them when in use. After this the lower grating cap is screwed on, and the filter is then ready for use.

Alteration in Arrangement of Charge for Smoke Cap Filters.—The following refers to changes which have to be made in the arrangement of the charge for the smoke cap filters, as before explained.

Experience has shown that the fragments of lime which are put in for the purpose of absorbing carbonic acid, become reduced to powder merely from the effects of the atmosphere, and are often quickly slaked by a man's breath. As these particles when pulverized render breathing very difficult, and it has been thoroughly ascertained that in fires carbonic acid is very seldom present in sufficiently large quantities to cause actual danger, it has been determined to remove the lime altogether, and to rearrange the other materials.

I have accordingly altered the arrangement as follows:—Half-an-inch deep of dry cotton wool, an inch deep of the same wool saturated with glycerine, half-an-inch deep of dry wool, an inch deep of fragments of charcoal, and an inch deep of dry wool. The other arrangements remain as hitherto.

It is of course to be understood that whenever carbonic acid is known or suspected to be present, a layer of fragments of lime may with advantage be added for immediate use, a corresponding portion of dry wool being removed for the purpose; but in such cases it is advisable to remove the lime shortly after use, and to replace the wool as before.

Each particle of smoke is in fact a piece of solid carbon or charcoal, carrying in it, and with it, a small load of noxious vapor, which produces greater irritation in the throat and lungs than even the solid particles; and there is always present in smoke some carbonic acid, which, though generally at our work in small quantities, is occasionally found sufficient to cause both trouble and risk to those inhaling it.

The dry cotton wool acts with great effect as a filter, arresting the larger portion and coarser particles of the opaque smoke.

The wool, moistened with glycerine, acts as a finer filter, arresting that portion of the opaque matter of the smoke which, from its tenuity, escapes arrest by the dry wool.

The charcoal arrests the invisible pungent vapors existing in the smoke, which no mere mechanical filtration would effect.

The lime absorbs the carbonic acid produced by the combustion or burning.

The succession of the layers may be changed without prejudice to the action, but for such rough business as ours it is well to have some dry wool in at least the following places, namely, on top, to prevent the taste of the glycerine, charcoal, or lime penetrating into the mouth, between the charcoal and lime to prevent their mixing, and at the bottom, to prevent the charcoal or lime falling out.

To prepare for putting on the smoke cap, take off the helmet, open a few of the top buttons of the tunic, and turn over the collar, breast, and back as low as possible without interfering with the free movements of the arms.

To put on the cap, hold it with the face part downwards, open the lacing sufficiently to allow the head to pass in, and taking the lower part of the sides or flaps in both hands, with the knobs and the ends of the thong hanging down, slip the hood over the head, and, as soon as the top rests on the crown of the head, adjust the wooden mouthpiece in the mouth, which will bring the eyeglasses and other parts in their proper places; tuck in the lower flaps under the tunic, take hold of the thongs in front, and pull on them until the lacing at the back draws the skull part close to the head all round.

It is not actually necessary to knot the ends of the thong in front, but it is convenient to do so, and in any case they ought to be tucked inside the breast of the tunic, lest they should catch in anything at work. After this, turn up and button the tunic, put on the helmet, and then all is ready.

Whenever convenient, it will be found a great advantage to plug the nostrils with pieces of any soft material that may be available, and thus prevent exhalations from the nose, which have a tendency to dim the glasses.

It is almost needless to mention that the hood may be put on with or without the respirator, as the latter can be coupled on and removed equally well whether the hood is on or off.

For practice the whole should be done by the man himself, without any help whatever.

With valves so very small and light as those necessarily used in an apparatus which is carried on a man's head, there is always more or less danger of their sticking in the seats or guards, especially when subjected to the combined action of heat, and of the vapor and water from a man's mouth; but this danger is generally obviated without any difficulty by the man either tapping the side of the respirator with his hand, or jerking his breath and blowing out any water which may have accumulated in the valve chamber.

The cap, with all fittings complete, is carried in a circular tin case about 10 in. long and 6 in. in diameter, with a capacity of 282 cubic inches, or less than one-sixth of a cubic foot.

The weights of the several parts are as follows:

	oz.	lb.	oz.
Hood with mouthpiece, thong, &c.		1	4
Respirator:			
Top cap	1¼		
Valve chamber tube, with top valve plate, valves, guards, connecting piece and swivel coupling	7¼		
Lower valve plate with valves, guards, and cylindrical part	2½		
Filter tube, with top grating	5		
Lower cap of filter tube	1		
	—	1	1
Charge		0	3
Tin case		1	8
Total		4	0

Summary of Weights.

	lb.
Hood and fittings	1¼
Respirator charged	1¼
Total as worn	2½
Tin case	1½
Total as carried	4

The Woolen Filter.—This is a very simple contrivance, but one more frequently used than perhaps all the others together. When none of the appliances previously mentioned can be obtained, a man who has to enter smoky places will find a great advantage in placing over his mouth and nose any woolen or other substance which will act as a filter, and intercept the grosser sooty particles of smoke.

Fireproof Clothing.—In connection with this part of the subject, though, as already explained, rather as a matter of scientific interest than of practical usefulness, the following description is given of an apparatus for enabling a man to pass through a furnace, and even to remain in it for several minutes.

Description of the Appareil Aldini.—In certain cases it may be indispensable to traverse flames in order to reach some particular spot, and it was for the purpose of preserving persons who find themselves in such circumstances that the Chevalier Aldini, an Italian physician, thought of the apparatus which bears his name.

This preservative apparatus consists of two vestments, one composed of a thick tissue of asbestos (*amianthus*), or woolen stuff, made incombustible by means of a saline solution, the other of a metallic cloth of iron wire covering the first garment, and mounted with a helmet on its upper part.

A person enveloped in these two garments can withstand the action of flames for some minutes without experiencing any dangerous effects, for on the one hand the external metallic tissue cools the flames, and on the other hand the internal tissue transmits the heat very slowly on account of the want of conductibility in the substances of which it is composed.

Aldini's apparatus dates at least from the year 1825, but, notwithstanding the good results which it has shown in the numerous experiments to which it has been submitted, it has never been adopted to any considerable extent, either because the circumstances in which it could be really of service are much too rare in comparison with the expense of its manufacture and maintenance, or because, as happens with a number of inventions, it presented in serious practice considerable inconveniences, such as rarely occur in experiments for mere show, where everything is generally arranged for the success of the operation.

The following is an account of one of the experiments made in Paris, in 1829, by some *sapeurs pompiers*, or firemen, with Aldini's clothing on: Two piles were erected of thin wood, covered with straw, ten yards long, two yards high, and distant from each other about a yard and a half; two lateral openings allowed the firemen to go out from the flames if they were compelled to do so, and in other ways facilitated the experiment, which consisted in traversing half the length of the burning heap, going out by one of the lateral openings and entering again by the opposite end, and then repeating the same experiment from the other side of the heap. The four firemen who were to make this trial were clothed in the new garment of metallic tissue; two carried, besides, a clothing of asbestos (*amianthus*) over a cloth garment, rendered incombustible by borax, alum, and phosphate of ammonia ; the two others had a double clothing of prepared cloth; each man had boots of asbestos, and under the foot a piece of cardboard of that substance; and one of them carried on his back a child, ten years of age, whose head was enveloped in a helmet of abestos. The firemen penetrated together into the interior of the double pile of flames, and, walking slowly, traversed it several times. At the end of 60 seconds, the child inclosed in the basket cried out so that the man who was carrying him was forced to retreat precipitately. They made haste to take out the child, who had in no way suffered; his skin was fresh, and his pulse, which beat 84 before the experiment, was only 96 after it. He could without any doubt have remained much longer in this wrapping, were it not for the fear which seized him, and which was caused by one of the straps supporting the basket having slipped a little on the shoulder of the fireman who carried it. The child, at the sight of the flames which roared below them, thought he had been thrown into them. A few minutes after he was as merry as usual, and felt no uncomfortable sensation. The fireman who carried the child had, before the experiment, 92 pulsations a minute, and after it 116. The three others remained in the flames 2 minutes and 44 seconds, and came out without having experienced anything except a sharp heat. The pulsations were before 88, 84, 72 a minute, and after 152, 138, and 124 a minute. The flame was continually fed with straw thrown upon that which was burning. There was very soon formed an enclosure of fire in which the firemen were shut up, and as a portion of the straw scattered on the ground threw up a flame which at times enveloped their legs, it was certain that the bodies of the men were exposed to the direct action of the flames. At a distance of more than six yards from the focus of the fire the heat was so intense that none of the numerous assembly could remain there. In other experiments the firemen were furnished with large shields, which they made use of to keep back the flames. It is obvious that such an apparatus as this could be of very little use for general work.

I have now gone through the principal appliances I can remember for the purpose of enabling men to work in smoke and other dangerous places, confining myself chiefly to some of those which have been to a certain extent brought into practical use, but adding one instance of what I must own to be rather a scientific curiosity than anything else.

There are thousands of other inventions which have been brought under my notice of late years in several countries, but none that I can remember at present which would be worthy of such consideration at such a meeting as this. It may be that in the discussion which I understand is to follow the reading of this paper, some new idea will be suggested, and, if so, I can only say that it will be heartily welcomed as an addition to the very small stock of knowledge which at present exists on the subject, and which, so far as my corps and I are concerned, would have been smaller still but for the cordial assistance we have received from my excellent friend, Professor Tyndall, to whom I beg leave to be allowed to offer my most sincere acknowledgments, not only for his generosity in giving us valuable information, which we have been enabled to turn to practical use, but also for his kindness and courtesy in supporting us by taking the chair on the present occasion.

Advices received recently from the United States report that large quantities of steel rails are being collected at New York by the Erie Railway Company, to be used in re-laying its track next year. At Chicago, also, a good inquiry is noted for steel rails, and there is a prospect of a considerable spring demand.

AMERICAN CARTOGRAPHY.

By S. V. CLEVENGER.

Written for Van Nostrand's Engineering Magazine.

The rapid increase of population in the United States, and consequent growth of the nation in internal and maritime industries, has produced a demand for more accurate knowledge of the topography of our country than was afforded by the various Marco-Polo sources upon which, in olden times, we were content to rely.

From necessity there has arisen a multitude of incongruous cartographic offices attached to the different departments of the Government, in some instances, several such offices belonging to one department, no two of which have identical systems, all varying in the degree and kind of skill employed in records and delineations; and, with a few notable exceptions, all failing to provide results at all commensurate with the annual appropriations made by Congress for their maintenance.

The U. S. Coast Survey is the most valuable institution, both for the unsurpassed accuracy of its achievements and its judicious methods for disseminating the information it obtains.

This office has been evolved from the commercial growth of the nation and the imperative need for precise information for coast defence. Its present magnitude is indicative of the high estimation in which it is held, and the efficiency of its operations is due to the undoubted abilities of the officers in charge, aided by the best and only correct system in the organization of its corps of assistants, cadetship, special training, and life-long service.

It has been especially free from the degrading effects of political preferment in the selection of even its humblest *attaché*, and to-day stands a monument of What Should Be among the ruins of What Is, in our intriguing Babylon.

The Hydrographic Service would, in its nature, seem to be an adjunct to the Coast Survey; but it is not, and far from it, it is amenable to a different department, although these two offices are, in a measure, inter-dependent.

The National Observatory and Hydrographic Office were originally connected, an incongruity probably less absurd than the present want of homogeneity in the relations of the numerous cartographical offices of the Government.

It is probably fortunate for the Coast Survey Office that it is not a part of the Navy Department, but it is decidedly unfortunate for the Hydrographic Service that it is not under the direction of the Coast Survey, inasmuch as the former could not exist, except with enormous expense, were it not for the operations of the latter. The War Department endeavors to collate notes and charts from various sources and has much "surveying" done, such as the locating military roads and establishment of reservation boundaries, the maps of which, except where the work is supervised by graduates of West Point, or skillful engineers, which is rarely the case, usually evince an utter ignorance of simple arithmetic on the part of the person charged with the execution of the survey.

Then the Quartermaster's Department must needs have maps wherefrom may be estimated the amounts due for transportation at certain rates per mile over innumerable roads, and it is safe to assume that nothing like accuracy has ever been attained in the measurements of these roads—the practice being to compromise disputed distances, and the presumption being natural that a distance not disputed has in it something of the nature of collusion between parties representing interests.

The postal routes are depicted by the Post-Office Department on a large map compiled from sufficiently inaccurate sources to warrant no doubt as to its incorrectness in general, though no blame may be attachable to the officials supervising its construction. In this department, as well as the Quartermaster's, millions of dollars are expended with these distances, accurate or false, as an element of the expenditures, and the probabilities being strongly against their correctness, it is not unreasonable to suppose that the government gains nothing by the errors.

The Engineer Corps, presuming it to be officered by graduates of West Point, trained there or elsewhere for proficiency in this special arm, is capable of being employed to greater advantage. Although its duties are, at present, somewhat restricted, the corps is not wholly kept from an occasional contribution to our geographical muddle. Considering all things, however, "Essayons" need not be ashamed of its maps.

It would be deplorable if the *ante bellum* efficiency of this service should be lowered by the admission of uneducated officers to any greater extent than has already been done.

An erratic system of geological explorations and triangations has gained something of a foothold which ultimately will become a well appreciated and valuable contributor to our cartographical lore. The results of several years surveys of this kind, made by different parties, civilian and military, are embodied in numerous hatchure maps with differing scales. Excepting the coast survey, the government has obtained the most information at the least cost from these explorations than from any other kind of surveys. The only objection to this class of work being the general one applicable to all—want of uniformity between different parties in their drawings and field notes, and the absence of anything like co-operation.

These parties are occasionally annoyed by an overlapping of areas, and surveys are re-made over fields previously traveled by another party. A commentary on the necessity for something approximating agreement and general design.

The Interior Department has charge of the execution of boundary lines between States and Territories, and the parceling out of public lands, adopting an independent and somewhat unique method of representing areas by sectional maps. Too much latitude is allowed contractors in running the lines dividing public lands to give maps thereof much importance beyond furnishing a good general idea of the country, and the difficulties in the way of a faithful representation of the surface, from this source is augmented by fraudulent work or "fudging" by the contractor.

This department must also have accurate statistics and maps of railroads, canals, Indian reservations, etc., which is not possible when the only exact knowledge we have of our interior is that it is somewhere within our coast line.

The public is by no means aware of the great amount of guess work resorted to by map compilers after searching all departments for information unobtainable, and what renders this condition of things inexcusable is that enough money has been expended by the government for surveys to have afforded a thorough survey of the entire globe.

The explanation of there not being a reliable map of the United States in existence, lies in the misdirected efforts of the many governmental offices, the want of organization and concentration of the numerous surveying bureaus, and what is most reprehensible, the fact that out of three thousand persons to-day employed by the Government, in geographical work, not more than three hundred know anything about the business, and these are principally members of the Coast Survey.

There is a remedy, and it is plainly indicated.

There should be a Cartographical office under the control of the Coast Survey Corps, or as efficient an organization as the Coast Survey, which cannot be found, and that office should have supervision of all surveys, whether geodetical, hypsometrical, hydrographic, or division of public lands.

Surveying, worthy of the name, is certainly not a *bagatelle* which may be intrusted to the unskilled workmanship of mediocre clerks. It is a science requiring considerable knowledge and special training, and when the coast, geological, hydrographic, land, postal, military, road, etc., surveys, shall have been consolidated into a thoroughly organized scientific bureau, then we may hope for some correct topographical information to be diffused at about one-third the cost to the Government of the present misappropriations.

ON THE THEORY OF IRRIGATION.

By FREDERICK CHARLES DANVERS, A.I.C.E.

From "Quarterly Journal of Science."

The great importance which the subject of irrigation has recently attained to in this country is no doubt primarily due to the forced necessity of utilizing our town sewage, and devoting it to profitable purposes, instead of, as has become the general practice, emptying into our streams and rivers, polluting their waters and destroying their fish. The advisability of adopting a system of irrigation in England has, however, of late years, become a necessity, and one which must annually increase in urgency, entirely irrespective of the subject of sewage utilization; and it is only by a proper appreciation of this fact, and of the causes to which it is due, that we can expect the subject will receive attention. In order to convey the full meaning of the foregoing remarks, it is necessary that we should consider, somewhat in detail, the true theory of irrigation, which will be found, as we proceed, to owe its origin to a disturbance, by the works of man, of the balance originally prescribed by nature between evaporation and precipitation.

A careful study of the works of nature, in their primitive state, cannot fail to show the beautiful harmony of creation, and the perfect economy of its arrangements whilst contributing only to the support of brute creation. To man, however, in his more elevated sphere, has apparently been given a certain power over the elements, by means of which he can disturb that harmony of existence, which not only is not violated, but is actually promoted by the lower orders of creation. The student of history, by applying this test in his researches into the records of past ages, will find that to man alone may be attributed such a disturbance of the balance of forces as, in progress of time, has led to serious convulsions of nature, affecting not only the geography of the earth, but also many atmospheric and climatic changes in different parts of the world, the occurrence of which there can be no difficulty in establishing. "If* we compare the physical condition of certain ancient countries at the present day with the descriptions given by old historians and geographers, of their fertility and general capability of ministering to human uses, it will be found that more than one-half of their whole extent—including the provinces most celebrated for the profusion and variety of their spontaneous and their cultivated products, and for the wealth and social advancement of their inhabitants—is either deserted by civilized man and surrendered to hopeless desolation, or at least greatly reduced in both productiveness and population."

There are two great primary causes which, above all others, may be said to have led to these remarkable changes; and these are, first, the destruction of forests; and, secondly, surface and subsoil drainage. We shall consider briefly these two subjects in the order in which they are mentioned above, and then proceed to show in what manner their evil effects may best be remedied.

It has been stated above that in the absence of human interference the natural law of consumption and supply keeps the forest growth, and the wild animals which live on its products, in a normal state of equilibrium,—and the perpetuity of neither is endangered until man interferes to destroy the balance, and this he does, not wilfully, but in order to contribute to his necessities. Thus, when the means of subsistence began to fail on such ground as had been left open by nature—and which must first have been subjected by man for the supply of his necessities—and as population increased, recourse was necessarily had to the removal of a portion of the forest that stood in the way of further extension of cultivation. A small quantity of wood only being required for fuel and buildings, fire was most probably resorted to in order to clear lands for agriculture, which method, as is well known even at the present day, renders the ground beneath especially suited for vegetation. Such indiscriminate destruc-

* "Man and Nature," by George P. Marsh; 1864, p. 3.

tion of forests necessarily caused a disturbance in the economy of nature by affecting the temperature and humidity of the atmosphere, thus causing considerable climatic changes; by influencing the local distribution of rainfall; and by its affect upon the flow of springs.

"Forests," says Becquerel,* "act as frigorific causes in three ways:—1. They shelter the ground against solar irradiation and maintain a greater humidity. 2. They produce a cutaneous transpiration by the leaves. And—3. They multiply, by the expansion of their branches, the surfaces which are cooled by radiation. As these three causes act with greater or less force, we must, in the study of climatology of a country, take into account the proportion between the area of the forests and the surface which is bared of trees and covered with herbs and grasses. We should be inclined to believe *a priori*, according to the foregoing considerations, that the clearing of woods, by raising the temperature and increasing the dryness of the air, ought to react on climate. The observations by Boussingault leave no doubt on this point."

With regard to the influence of forests upon humidity, it must be remarked that the vegetable mould, resulting from the decomposition of leaves and of wood, whilst it helps to obstruct the evaporation from the mineral earth below, absorbs the rains and melted snows that would otherwise rapidly flow away. This moisture it subsequently parts with gradually by evaporation and percolation. The water absorbed by the roots of a large tree has been found to be greatly in excess of the weight of that fluid which enters into new combinations resulting in its growth, and the superfluous moisture must somehow be carried off almost as rapidly as it flows into the tree. "Recent experiments† on this subject by Von Pettenkofer were made with an oak tree, extending over the whole period of its summer growth. The total amount of evaporation in the year was estimated at 539.16 c.c. of water for the whole area of its leaves. The average amount of rainfall for the same period was only 65 c.c.; and the amount of evaporation was thus 8½ times more than that of the rainfall." This evaporation of the juices of the plant, by whatever process affected, takes up atmospheric heat and produces refrigeration, increasing, at the same time, the humidity of the air by pouring out into the atmosphere, in a vaporous form, the water it draws up through its roots.

Although the destruction of forests can hardly be said to influence the total amount of rainfall, it has, no doubt, owing to the circumstances above mentioned, no small effect upon its distribution. The most obvious argument in favor of this supposition is that the summer and even the mean temperature of the forest is below that of the open country adjoining. This must reduce the temperature of the atmospheric stratum immediately above it, and, of course, whenever a saturated current sweeps over it, it must produce precipitation which would fall upon or near it.

The manner in which forest destruction has most directly led to the necessity for irrigation, is, perhaps, the effect which it has upon the flow of springs. The roots of forest trees penetrating far below the superficial soil conduct the water accumulated on its surface to the lower depths to which they reach, and thus serve to drain the superior strata and remove the moisture out of the reach of evaporation. This ensures the permanence and regularity of natural springs, not only within the limits of the wood, but at some distance beyond its borders, and so contributes to the supply of an element essential both to vegetable and animal life. As the forests are destroyed, the springs which flowed from the woods, and, consequently the greater watercourres fed by them, diminish both in number and in volume. Boussingault, in his "Economie Rurale," remarks that, "since the clearing of the mountains in many localities, the rivers and the torrents, which seemed to have lost a part of their water, sometimes suddenly swell, and that, occasionally, to a degree which causes great disasters. Besides, after violent storms, springs which had become almost exhausted have been observed to burst out with impetuosity, and soon after to dry up again." Arguing from the basis of facts already established, he draws the

* "Des Climats et de l'Influence qu' exercent les Sols Boisés et Non-Boisés."

† "Quarterly Journal of Science," October, 1870, p. 524.

conclusion that forests have a special value—"that of regulating, of economizing in a certain sort, the drainage of the rain-water."

To sum up the results consequent upon the clearance of forests, as already set forth, it may be briefly stated that any undue extent of interference with the economy of nature in this respect cannot but be followed by the drying of the vegetable mould on the surface of the ground affected by the clearance; and it soon becomes removed by the alternate action of wind and rain, leaving behind a sterile soil, possessing none of the properties necessary for cultivation; but not, fortunately, beyond the power of man to restore, in course of time, to its former powers of reproduction. The means for effecting this are the same which, if adopted earlier, would have prevented its falling into a state of sterility, viz., the artificial application of water to the soil, so as to counteract, in some measure, the consequences necessarily arising from an interference with the proper proportion prescribed by nature of forest to open land.

Having now considered the effects caused by the destruction of forests, we have, in the next place, to trace, in a similar manner, the probable evil consequences of land drainage.

Surface-drainage is a necessity in all newly-reclaimed lands, and probably dates its origin from the commencement of agriculture; but the construction of subterranean channels for the removal of infiltrated water, marks ages and countries distinguished by a great advance in agricultural theory and practice, a large accumulation of pecuniary capital, and a density of population which creates a ready demand and a high price for all products of rural industry. Under-drainage being most advantageous in damp and cool climates, where evaporation is slow, and upon soils where the natural inclination of surface does not promote a very rapid flow of the surface waters, it is not surprising to find that this practice has been carried further, and a more abundant pecuniary return obtained from it, in England than in any other country.

By removing water from the surface of the soil, however, the amount of evaporation is necessarily lessened, and the refrigeration which accompanies all evaporation is diminished in proportion. Accordingly it is a fact of experience (as stated by Marsh in his "Man and Nature" previously referred to) that, other things being equal, dry soils, and the air in contact with them, are perceptibly warmer during the season of vegetation, when evaporation is most rapid, than moist lands with the atmospheric stratum resting upon them. Under-drains, also, like surface-drains, withdraw from local solar action much moisture which would otherwise be vaporized by it, and, at the same time, by drying the soil above them, they increase its effective hygroscopicity, and it consequently absorbs from the atmosphere a greater quantity of water than it did when, for want of under-drainage, the soil was always humid, if not saturated. Under-drains, then, contribute to the dryness as well as to the warmth of the atmosphere, and as dry ground is more readily heated by the rays of the sun than wet, they tend also to raise the mean, and especially the summer, temperature of the soil.

Although the immediate improvement of soil and climate, and the increased abundance of the harvests have fully testified to the advantages of surface and subsoil drainage as adopted in England; its extensive application appears to have been attended with some altogether unforeseen and undesirable consequences, very analagous to those resulting from the clearing of the forests. The under-drains carry off very rapidly the water imbibed by the soil from precipitation, and through infiltration from neighboring springs or other sources of supply. Consequently, in wet seasons, or after heavy rains, a river bordered by artificially drained lands receives in a few hours, from superficial and from subterranean conduits, an accession of water which, in the natural state of the earth, would have reached it only in small instalments, after percolating through hidden paths for weeks or even months, and would have furnished perennial and comparatively regular contributions, instead of swelling floods to its channel. By thus substituting swiftly acting artificial contrivances for the slow methods by which nature drains the surface and superficial strata of a river basin, the original equilibrium is disturbed; the waters of the heavens are no longer stored up in the earth to be gradually given out again, but are hurried out of man's domain with wasteful haste; and while the inundations of the river are sudden and disastrous, its current, when the drains have run dry, is reduced to a rivulet.

It has thus been shown that a great similarity ex sts in the consequences arising from the destruction of forests and from land-drainage, both as they affect the temperature and humidity of the atmosphere and soil; which, in their turn are, with a good show of reason, supposed to have a considerable effect upon the distribution of rainfall, though not, perhaps, upon the actual amount of it. It is impossible to restore the harmony of nature thus once disturbed, without allowing the lands, cleared and improved, to revert to their original state; but as this would be detrimental rather than conducive to man's interests, it is more desirable that the balance should be restored in other ways, and by other means, which, whilst counteracting the evil effects above referred to, admit of the retention of the land in its improved state of productiveness. Thus, by the artificial production of moisture in the soil, by means of irrigation, the equilibrium may be restored; whilst the subsoil drainage which has in many cases rendered a resort to irrigation necessary, is in itself essential to the proper development of cultivation by irrigation; otherwise the land, especially in heavy soils, is liable to become waterlogged, to the injury alike of the crops and the health of the nerghborhood. This latter is clearly proved in the case of rice crops, which are so notoriously injurious to health that no European can with safety sleep in their vicinity. "Not only does the population decrease where rice is grown," says Escourron Milliago, "but even the flocks are attacked by typhus." This is happily not the case where simple irrigation is adopted for the growth of grass, cereals, vegetables, and other crops required in European countries generally, where proper attention is paid to subsoil drainage. The reason why land will not produce good crops in the absence of a sufficient amount of water, even though it be highly manured and otherwise well cultivated, is that moisture is essentially necessary for the admixture with the soil of those invigorating properties existing in manures, which, in the absence of that agency, would, though mechanically mixed with the earth, remain chemically separate and distinct from it, and, therefore, not in such a state as to be in any way beneficial for the development of growth in herbage or plants. With the assistance of water, however, the salts contained in manure are set free and eagerly unite with the soil, by which they may be said to be digested and prepared to become fit food for the nourishment of vegetation; but, even when so taken up, these salts are, during seasons of drought, held from vegetation with an iron grasp by the soil, from which moisture alone can again loosen them. Thus, we see that, whilst moisture is required in order to cause a chemical combination between the constituents of the manure and the soil, it is also further required before that soil will yield up the properties thus obtained for the purpose of vegetation.

Having now considered in what manner irrigation has been rendered a necessary adjunct to cultivation, it remains but to state briefly what steps are required for the conservancy of rainfall in order to render it most conducive towards a restoration of that balance in nature which previous operations of man have tendered so seriously to disturb. These are two; namely, the prevention of waste by storage, and the construction of channels for the proper distribution of water so collected, properly fitted with mechanical appliances for the regulation of the supply to different fields or districts as it may be required.

It is not the object of the present paper to enter into any account of the works or contrivances necessary for the collection and distribution of rainfall and drainage water; some brief allusion to what has been done in this respect, in former ages and in other countries, has already been made in the pages of this journal, but a complete study of the history and engineering nature of such works would occupy more space, and deserve more attention, than could be given to the subject in the concluding part of an article which has already occupied so much space; it may, however, be considered of sufficient importance to form the theme for a separate article upon some future occasion. In conclusion, it may be remarked that the question of sewage irrigati n is one entirely distinct from that of simple irrigation by means of water alone; the purposes of the one being but the application of moisture to the soil, it in no way supercedes the necessity for manuring, whilst the former combines the application of manure together with irrigation. It does not seem at all probable that the two systems will ever be carried out in conjunction with each other, neither is it necessary that they should be combined. It is also clear that, whereas sewage irrigation is only practicable to a certain limited extent, and in localities bordering upon towns or places where a number of human habitations are congregated together, irrigation in its simple form may be adopted, to a greater or less extent, wherever land is brought under cultivation.

SOME RECENT DEVELOPMENTS IN THE TECHNOLOGY OF IRON.

From "Iron"

Among the traditional sayings handed down from generation to generation, as embodying the accumulated experience of centuries, none recur more frequently than those which enunciate with singular unanimity the unpalatable truth that adversity teaches lessons more valuable and indispensable than any we care to learn in times of brighter fortune. "The pupils of misfortune are the aptest scholars:" "Adversity is the road to prosperity"—such is the burden echoed through the proverbs of all nations and all times. There are, moreover, few of us who do not have frequent—often, as we think, *too* frequent—opportunities of putting the assertion to the test, and it is well for us if we prove its truth. Those engaged in the manufacture of iron—one of the most precarious as it is certainly the greatest of human industries—have now such an opportunity. They are passing through one of those periodically recurrent phases, if not of actual adversity, yet of considerable depression and stagnation, of which the duration may be indefinitely prolonged.

It seems, therefore, a fitting time to turn to account the enforced leisure which accompanies such negative crises, by reviewing the more recent developments of the science and practice of the iron metallurgy, with a view to their application on the return of more prosperous days, whose advent nothing would so much tend to accelerate, as an enlightened attention to those economic details by which alone the cost of production can be lowered, so as to enlarge again the now untowardly slender margin of profit. The more so, as there is no season so propitious to the improvement of plant, the trial of novelties, and the modification of processes, as a time of slackness. Under the high pressure of the past few years invention after invention has been developed, many being of approved practical value, and all aiming at the introduction of fundamental changes in the existing course of manufacture. A number of these inventions are of American origin, and we must look to ourselves lest we find the Americans, with their extraordinary natural advantages, aided by a practical ingenuity probably superior, and certainly not inferior to our own, not only driving us out of their own markets, but proving formidable rivals on neutral ground. Hitherto the United States, despite their enormous deposits of ore and fuel, have labored under the disadvantage of the fuel being, in the majority of cases, in situations far removed from the ore grounds. This is notably the case with the pure and abundant ores of the Lake Superior district. The rapid progress of railway building, and the discovery of fresh coal fields, together with the successful application of inferior fuel, tends, however, to reduce this drawback to a minimum. It is probable also that, when the excessive depression which now prevails in the States passes away, labor will be materially cheaper, and scientific methods will supersede much of that wasteful and careless practice which protection and an ever-increasing demand permitted, not only to exist, but to prosper. Simultaneously with a remarkable advance in the practical details of metallurgical appliances and processes, there has been a not less conspicuous extension of the boundaries of our theoretical knowledge. Since the publication, in 1864, of Dr. Percy's admirable treatise, which (with the exception of Truran's work, which deals with the subject almost exclusively from the engineer's point of view) was the first contribution of real importance to the technical literature of iron by the greatest iron-producing nation in the world, there has been hardly any effort to deal comprehensively with the additional facts and observations which have accumulated year by year, through the labors of a constantly increasing band of scientifically trained investigators. It is to be hoped that a new edition of Dr. Percy's work, embodying recent results and progress, may be soon forthcoming, so that we may have the advantage of his judgment on matters on which he is so well qualified to give an opinion. In the meantime, the meetings of the Iron and Steel Institute, as well as those of the various engineering and scientific societies, have served as an arena for the discussion of some of the more important questions thus raised, though the possibly unavoidable intrusion of personal feeling may at times have somewhat obscured the views and prejudiced the impartiality of the controversialists, and rendered the more desirable an independent retrospect of the conclusions actually arrived at. So important, however, are the interests involved in the proper appreciation of these investigations and discussions, that it may be well to examine *seriatim* the various chemical and technical considerations on which they depend.

The first and most important process in the manufacture of any metal is unquestionably its reduction from its ore. The only ores actually worked for the production of iron are the sesquioxide (better known as hæmatite, or brown hæmatite, the latter being a hydrated variety); the magnetic oxide, Fe_3O_4; and the carbonate or spathic ores, among the latter are included the clay ironstones so extensively worked in Wales, Stafforshire, and Cleveland, and the Scottish blackband. On calcination, the carbonates part readily with their carbonic acid, and are simultaneously oxidised, mainly to the sesquioxide (Fe_2O_3). Thus the question of reduction is practically narrowed to the consideration of the most speedy and economical means of depriving of their oxygen these two oxides, Fe_3O_4 and Fe_2O_3; and, indeed, the magnetic oxide is so rarely smelted in this country that we need hardly concern ourselves with any other than the sesquioxide, under the various physical conditions in which we find it. Unfortunately, however, the reduction is complicated, especially in the cases of the carbonates, which constitute the bulk of English ores, by the necessity of getting rid of the gangue or earthy matter intermixed with the ore. This earthy matter, consisting mainly of silicate of alumina and free silica, is infusible, unless its fusion be assisted by the presence of some body with which it may unite to form a fusible silicate. Lime serves this purpose admirably, and its presence not only assists in the formation of a sufficiently fusible slag, but also serves to prevent the loss of iron in the slag, which its protoxide would otherwise form with the silica. Should the gangue itself be calcareous, silica becomes the approximate flux. Obvious as are the theoretical advantages (hereafter to be more fully treated of) which attach to the *direct* production of steel and malleable iron from the ore, the *indirect* process, in which pig is produced, not only for foundry purposes, but also as a preliminary to the production of forge metal and steel, has, in England, owing in some measure to local circumstances, obtained a development so gigantic, to the total exclusion of the older bloomery furnace, that it clearly has the first claim on our consideration. It is, moreover, in the chemistry of the blast-furnace that the greatest strides have been recently made, establishing, indeed, such an advance on our previous knowledge as to remove the operations taking place in that elaborately simple, yet gigantic, structure altogether from the domain of mere technical empiricism. Among the more recent laborers in this field have been Gruner, Tunner, Schintz, and, above all, our countryman, Mr. I. Lowthian Bell. It is chiefly to him that we are indebted for those precise determinations and logically-drawn conclusions which have at last given a sound experimental basis to our theorizing on the complicated changes which occur in the interior of the blast-furnace, while he has afforded the commendable example of a hereditary and successful ironmaster, not only organizing a well-conceived course of experimental investigations, but having the candor and sagacity to throw open the fruits of the experienced thus gained for the free use of his manufacturing rivals.

The changes of which the blast-furnace is the seat, regarded in their simplest form, are the oxidation of the fuel by the oxygen of the blast; reduction of the oxide of iron; carburization of the reduced iron; and, finally, fusion of the carburized metal with formation and separation of the slag. If, however, raw carbonates are used, their calcination, or the removal of their carbonic acid, takes place in the upper part of the furnace; while in all but freshly calcined ores there is present a certain amount of moisture, which is also expelled near the top of the furnace. Then again, there is the calcination of the limestone, in which form the requisite amount of lime is generally charged into the furnace. The reduction of silica, sulphates, and phosphates, is yet another minor operation, with which the ironmaster would be glad to dispense. One frequently finds the ingenuity of metallurgical writers displayed in the accurate division of the interior of the blast-furnace into horizontal zones, marked with regular boundaries, to the several spaces within which it suggested that each of these actions is confined. Thus we have the zone of preparation, of reduction, of carburization, and of fusion. The futility of this arbitrarily precise topography was pointed out by Dr. Percy, but its inaccuracy has been still further disclosed by subsequent observations, which tend to show that any division other than a distinction between the melting zone and non-melting zone would, except as a matter of convention and convenience, be groundless.

In each of the operations indicated—which, however, are far from exhausting the list of actual reactions—heat is absorbed or produced, and the theoretical simplicity of the reducing action is modified to an embarrassing extent. The agencies by which these effects of reduction, and heat-production, and carburation are effected are mainly carbonic oxide and solid carbon, the former playing the larger part. The cyanides and cyanogen, hydrogen and ammonia, nevertheless have a certain auxiliary influence on the results, while it will be seen that a comprehension of the modifying or negative action of carbonic acid is absolutely necessary at the outset. It will be the most convenient course to assume for the present the presence of these bodies, and examine their individual action upon oxide of iron before considering their relative importance in the actual operations. Dr. Percy disposes of the subject in the following paragraphs, which perhaps sufficiently summarize all that was then accurately ascertained on the subject: —"Sesquioxide of iron," says the doctor, "is easily reduced to the metallic state when heated to redness in contact with carbon, carbonic oxide, hydrogen, ammonia, or cyanogen. When reduction by any of these agents takes place at a comparatively low temperature, the metal is left in a pulverulent state; when the temperature is high a coherent mass of malleable iron is produced, which may be readily forged with the solid metal. . . . In reduction by hydrogen, magnetic oxide is first formed." This, with the exception of some observations on reduction by solid carbon, was about the limit of our acquaintance with the action of reducing agents on iron ores, unless we except Ebelmen's experiments on the changes which materials undergo in their descent through the blast-furnace, in which there were neither analyses taken of the gases, nor were the conditions such as to allow of reliable conclusions being arrived at.

It has been stated that carbonic oxide is the most operative of the various reducing bodies present, and it was to ascertain the conditions and modes of its action that Mr. Bell's experiments were chiefly directed. He found that on passing pure carbonic oxide over calcined Cleveland ironstone it began to be deoxidized at about 210 deg. C., but at this temperature only 28 per cent. of the oxygen present was removed in an hour. At about 415 deg. C., the proportion of oxygen removed in an hour was nearly 6 per cent. This latter temperature is that fixed by Gay Lussac and other experimenters for the first signs of reduction taking place. Now, this temperature is but little over that of the escaping gases of an average blast-furnace, so that, as far as their carbonic oxide is concerned, it might begin its reducting action from the moment of charging. By a six hours' exposure to carbonic oxide at something under this temperature, from 37 to 50 per cent. of the oxygen was removed. An exposure of 3¾ hours at a bright red heat cost the ore 90 per cent. of its original oxygen. By a longer exposure to a bright red heat, with carbonic oxide, the remaining 10 per cent. of oxygen was reduced in amount, but there always remains a certain small proportion of oxygen, which Bell suggests to exist as a suboxide, Fe_2O. This leads to the consideration of the mode in which the reduction by carbonic oxide is effected. It was discovered by Caron that carbon was deposited on oxide of iron when exposed to carbonic oxide at a temperature under redness, a fact independently observed by Schintz; Bell, however, carrying further these experiments deduces from them very important conclusions. He found that at a temperature but little over 200 deg. C. carbonic-oxide deposits on the oxide over which it passes minutely-divided carbon. It is, however, at temperatures bordering on 450 deg. C. that this phenomenon is most pronounced. The oxide at this temperature, soon after the commencement of the reduction, cracks, swells up, and is not only covered externally with a deposit of powdery carbon, but its interior is simultaneously penetrated with the fine deposit. M. Gruner and other French *savants*, who have repeated and studied these experiments, consider that the formation of metallic iron is necessary to initiate the deposit of carbon, but Mr. Bell believes that it is the presence of some suboxide which induces the splitting up the carbonic oxide. The weight of carbon thus deposited is very variable. In some cases the carbon deposited on hæmatite will equal five times the weight of the iron present. At other times, under apparently identical conditions, the carbon will be less in weight than the iron. In all cases the deposit on calcined Cleveland is immensely less than that on hæmatite or precipitated oxide. On the function of the deposited carbon there is also some divergence of opinion, but there can be little doubt that the carbon thus penetrating the oxide effects the removal of oxygen after the gas has exhausted its deoxidizing power. It would appear, however, notwithstanding Dr. Percy's dictum, that the last traces of oxygen cannot be removed even by the joint agency of the carbon and carbonic oxide at a full red heat; the deoxidation being only terminated when fusion has taken place. Carbon deposition, as would be anticipated, diminishes rapidly at temperatures approaching redness, and ceases entirely at a red heat. These researches throw considerable light on the discussion between Le Play and Gay Lussac as to the relative importance of carbonic oxide and solid carbon as reducing agents.

It is not surprising that the molecular and mechanical condition of the oxide should materially affect the readiness with which deoxidation overtakes it, and experience abundantly demonstrates that this is the case. Thus Fe^2O_3, precipitated from a solution by ammonia, is far more susceptible to deoxidation than any natural oxide, and carbonic oxide commences to reduce it at 150 deg. C. Of more practical value are observations on the relative behaviour of the natural ores, but in this direction there is a deficiency of experimental information, the greater part of Mr. Bell's experiments having been carried out on Cleveland stone. As instances of this differing reducibility we have—

								Original Oxygen.	
Calcined Cleveland,	40	pr. cent. iron,	exposed for	7½	hours to CO,	losing	at 410.C,	20	pr. cent.
Calcined Spathose Ore,	52	"	"	"	"	"	"	28	"
Lancashire Hæmatite,	40	"	"	"	"	"	"	57	"
Calcined Cleveland,	"	"	"	7	"	"	417.C,	9.4	"
Calcined Cleveland,	"	"	"	6	"	"	410.C,	37	"
Lancashire Hæmatite,	67	"	"	6	"	"	"	36	"
Elba Specular Ore,	68	"	"	6	"	"	"	17	"
Calcined Spathose Ore,	52	"	"	6	"	"	"	15	"

These results appear at first sight hopelessly anomalous, nor, indeed, have the apparent contradictions been satisfactorily explained. In one case we have a poor hæmatite deoxidized to thrice, and even five times the extent of Cleveland stone subjected to the same influences; in another we find a rich hæmatite actually less susceptible than Cleveland ore. Doubtless the difference in the results is in part due to a difference in the speed of the current of gas to which the ores were exposed; but the question being a vital one in blast-furnace economy needs further elucidation. Experimenting on further samples of the last four ores in the table above, with a gas current four times more rapid than that used in the previous experiments. Bell found the results considerably modified. Thus while the hæmatite lost 71 per cent. of its oxygen, the Cleveland lost only 50 per cent., the spathose 42 per cent., and the specular ore 18 per cent.

Metallic iron has also the property of dissociating carbonic oxide at temperatures between 300 deg. and a bright red heat, with deposition of carbon and the formation of an infinitesimal amount of oxide.

The action of carbonic oxide in reduction is greatly modified by the fact that the carbonic acid, which is the product of its oxidation, has on spongy metallic iron an oxidising influence; this action commences between 300 deg. and 400 deg., and becomes more energetic as the temperature rises, the product being, at the lower temperatures, an oxide or mixture of oxides, of indefinite composition. Spathic carbonates and the protoxide are converted under the influence of carbonic acid to the magnetic oxide. It will be readily recognized that this oxidising action of carbonic acid constitutes a formidable obstacle to the completion of deoxidation by carbonic oxide, and sets up an impassable limit to the theoretical reducing power of a given volume of carbonic oxide, varying with the temperature. A study of the action of mixtures of the two gases becomes essential, and confirms this conclusion. The point first to be determined is the relative proportion of carbonic oxide necessary to prevent carbonic acid exerting this oxodising influence on the newly reduced metal. At a temperature of something over 400 deg. C., or about that of the throat of the furnace, we find a mixture of equal volumes of the two gases is neutral; but at a red heat the oxidising tendency becomes predominant, while at a white heat it requires a dilution with nearly ten times its volume of carbonic oxide to check the oxidising effect of carbonic acid. We are thus prepared for the case which actually occurs in the blast-furnace, and on which the development of its ultimate economy reposes.

It is to be observed that the removal of the first portions of oxygen seems in all cases to be much more easy than is the case when the reduction has proceeded to a certain point, each remaining particle of oxygen seeming to cling with increasing tenacity to the metal. A mixture of one volume of CO with six of CO_2 removed in half an hour 6 per cent. of the oxygen in calcined Cleveland at a low red heat, and this appears to be the point of equilibrium beyond which the action will not proceed; but even when the CO_2 was reduced to twice the volume of CO the mixture only removed twice the amount of oxygen in thrice the time. At a red heat, calcined Cleveland hæmatite and spathose ore were alike reduced to the condition of protoxide by equal volumes of the two gases. This is a very noteworthy experiment, which, taken in conjunction with the circumstance that metallic iron, under similar conditions, became oxidised to the condition of protoxide of iron (a fact first brought into prominence by Debray), points distinctly to the conclusion that such a mixture at the temperature indicated would only take up one-third of the total oxygen in the ore. Further experiments lead to the important practical position that at about 417 deg. C. a mixture of 100 volumes carbonic oxide and 31 volumes carbonic acid exercises on calcined Cleveland ore an inconsiderable deoxidising influence, and that this influence is still more insignificant when the carbonic acid is to the carbonic oxide as 1 to 2, being hardly equal to a removal of 10 per cent. of the original oxygen in eleven hours, and in some cases the removal being considerably less. At a red heat, however, the reduction is more rapid and considerable.

RAILWAY SIGNALS.

From "The Engineer."

The chairman of one of our most important railways recently stated that the introduction of the block system on that line would increase the working expenses by between £200,000 and £300,000 per annum, and he expressed grave doubts that this enormous expenditure would really diminish the number of yearly accidents or augment the safety of the public. We know that railway authorities one and all regard the block system with doubt, and look on it as something that has been forced upon them, and which they could do better without. This unanimity of opinion lends weight to the arguments on which it is based; and these last should not be dismissed, as they too often are, without due consideration. Broadly stated they are two in number. It is urged that the block system interferes grievously with the manipulation of traffic, especially on crowded lines and at busy seasons of the year, and no doubt this is to some extent true; but the safety of the public must be considered before all things, and if traffic cannot be carried on with as much ease to the officials and with as little cost to the railway companies when the block system is in use as when it is not, then the officials and the companies must rest content to do the best they can, and to, in a sense, sacrifice their interests for the protection of travelers. The second argument against the block system is that it does not do what it is intended to do, and we have reasons to believe that this statement is but too well founded. The defect lies, however, we think, not in the system, but in the way in which the system is worked, and it is our object now to call attention to this point.

Under the block system a line of railway is cut up into sections of various lengths according to conditions principally dictated by the frequency with which trains follow each other. On lines of small traffic, four, six, or even ten miles may intervene between one block station and the next, while on our metropolitan lines the distance is usually reduced to a very few hundred yards. The theory is that two trains shall never be found at one time on the same line of rails between any two block stations. If this theory could be carried into practice the block system would work perfectly, and no collisions could occur except in one way. If a tie bar broke it is possible for carriages or wagons to be left on the road, the train going on and passing the next station the signalman would give the line clear back to the next block, and the following train would then run into the carriages standing on the line. A collision of this kind, however, is not likely to take place, because the signalman at B ought not to unlock the line for A unless he saw that the train was complete. It may also be pointed out that the guard of that portion of the train left standing on the line would take measures to avert any train following him; but it is obvious that if an accident were averted in this way, the fact would go for nothing in favor of the block system, which would have no power to interfere once a train passed A on its way to B. If the signalmen are really vigilant and experienced no such accident as that which we have described ought to happen under the block system. But collisions, some of them of a very alarming character, do occur when apparently every precaution is observed, and that on lines where the block system is very carefully worked. Some of them occur because in station-yards and at junctions work has to be done to which the block system does not directly apply. But a very considerable proportion are due to another cause, which the block system ought to eliminate altogether. It may not be generally known that the Board of Trade investigate every accident, great or small, which has put the lives of passengers directly or indirectly in jeopardy. The particulars of these investigations, the evidence of the witnesses, and the report of the officer who conducts the inquiry are all printed with tolerable promptitude, and circulated pretty freely. They find their way to journalists with commendable regularity. A very moderate acquaintance with these documents will show that a surprisingly large number of collisions occur under existing arrangements; some of them are very serious accidents; the fact that they are not all so is, of course, not due to the block system. It may be asked how such a state of affairs is possible. The answer is easily supplied. Collisions occur because drivers do not attend to the signals, or because the signals cannot be seen or do not act with decision. They are also sometimes due to a mistake on the part of the signalman. To this class of accident we shall not further refer here, we shall confine our attention to the mistakes made by engine-drivers and guards.

In very many instances when a collision occurs the engine-driver says the signal was all right, and the signalman says it was not, and it is a work of no small difficulty to decide between them. A rather bad smash occurred on a Northern railway not long since. The engine-driver and his fireman said—as usual—that the signal gave line clear; the signalman, as usual, said that it did not. An inspection of the signal showed that both parties were in a sense right; that is to say, the signalman could set the lever in his box at danger, while the semaphore gave a doubtful indication which might be interpreted either way. In many cases, however, there is no room to doubt that drivers do run past signals without seeing them. Thus, in a collision case recently investigated, the driver was trying to get some water into his boiler, the injector acting badly, while the fireman was bringing coal down on the foot plate. They ran past a signal undoubtedly at danger without knowing it. It is not, however, necessary to insist on a fact well known to all railway men. Trains are run in foggy weather on a very haphazard system unless the fog is so bad that detonating signals are necessary. Signals are passed and no one gets a glimpse of them; and the same thing often takes place even on tolerably clear nights. Indeed, the wonder is, not that signals are not seen, but that they are, if we consider the short time available for picking them out on a "dirty night," and the number of things to which drivers, stokers, and guards have to attend as well as to signals. We shall not attempt to dwell on minor causes which conduce to the obscurity of signals, such as placing them too high, or too low, or in a bad position. It is enough to say that none of these causes could operate effectually if it was not that railway signals as now made, whether on the block or any other system, apply to the sense of sight only. Here is the grand defect, and until this is removed the block system cannot secure that immunity from accident which it professes to be able to give us, and it is quite possible that as much as £300,000 a year may be spent on a great line without making traveling very much safer.

It will be urged, we know, that railway signals have always appealed to sight alone, and that precedent is absent as regards anything else; but the last argument is hardly true, because when it is obvious that signals might just as well have no existence as far as the sense of sight is concerned, the platelayers are sent "fogging." There is, we are glad to see, a gradual drift of opinion in favor of something more certain than the semaphore; not that the semaphore is to be got rid of, but supplemented. In a word, more senses than one of those on the foot-plate are to be appealed to. The doing of this is a very simple matter; if it were not it would have been done long ago. But, as usual, ingenious persons begin to make difficulties where none exist, and within the last few years we have received numerous proposals for making sound-signals, manifesting the most perverse ingenuity. A favorite device is, that locomotives are to make contact in passing signals, and electric bells are to be rung on the engine. A complex and bulky paraphernalia of galvanic batteries, commutators, and wires form an essential feature in these devices, which we should be sorry to see adopted. To Mr. Stroudley and Mr. Banister, of the Brighton line, is due the credit of being the first to introduce in a practical form a supplementary signal. The arrangement now on trial is so essentially simple and so directly appeals to railway perceptions that it could never have originated with an outsider. Engine-drivers are peculiarly sensitive to the state of the road over which they may be running, and they can detect an unusual jolt or jerk with the utmost precision. Mr. Stroudley avails himself of this sense of touch, so to speak, when the semaphore is set to danger, in the following way:—

Through a cast iron guard secured to the rail by two of the ordinary chair keys are passed two plates of thin steel about ¼ in. thick by 3 in. wide. They are placed horizontally about 6 in. apart. When the signal is put to danger the plates are pushed through the guard on to the top of the rail, on which they lie side by side. The wheels of the engine must pass over these plates if the driver neglects the signal, and in so doing he receives three specific jolts—one for each wheel. Nothing more powerfully arouses the attention of a driver to a sense of danger than an unusual motion on the part of his engine, and Mr. Stroudley's "jolter" signal is, therefore, far more certain to prove effectual than any red light or detonator. It is impossible for those on the foot-plate to make a mistake. If they run past the signal they must know that it is against them. So far, the device has worked perfectly. Sound-signals can also be given with great ease and certainty by making a light lever on the engine come into contact with a fixed stop interposed by the act of setting the semaphore to danger, and so blow a whistle or sound a gong on the foot-plate; but unless several matters of detail are carefully attended to this device cannot be applied with success. A design of the kind was submitted to us some time since, which is exceedingly neat and simple, and of which we may have more to say. One feature in the invention is that if a driver runs past a signal the fact is recorded against him.

We believe that the difficulties that lie in the way of adopting supplementary sound or touch signals are really very insignificant, and that without them the block system can never be considered approximately perfect. We pronounce no opinion as regards the merits or the demerits of the block system, except that an argument against it of considerable weight would be removed by extending the range of signal perception by calling in other senses than that of sight; and in shunting and yard work generally such supplementary aids will prove peculiarly valuable at night and in severe weather. We hold that it is better to do without an apparently good thing if it is complex and likely to get out of order; and we now urge upon railway authorities a consideration of our arguments in favor of the adoption of supplementary sound or touch signals, only because they can be almost elementary in their simplicity although perfectly efficient. If any one doubts that they would prove useful, we point to the reports of Colonels Yoland and Riche and Captain Tyler as our answer.

COTTON GUNPOWDER.

From "Engineering."

Under the above name another member was lately added to the steadily increasing family of violently disruptive compounds. This explosive is of the gun-cotton glass, although it differs greatly from gun-cotton proper, both in appearance and character, inasmuch as it is a fine powder of a pale yellow color, and, it is stated, can be exploded with a cap direct after having been saturated with 20 per cent. of water. It is in fact a perfected development of what was three years since brought before the public as Punshon's gun-cotton, which consisted of gun-cotton toned down with sugar, and possibly some other ingredient until it could be—and was in our presence—used in a rifle. But the cotton gunpowder of to-day could not be used in a rifle without bursting it, so local and so powerful is its action; neither is it at present intended to be so used, the company who are now manufacturing it confining their production to a material for blasting only, which they make in two strengths, Nos. 2 and 3, No. 2 being the stronger and adapted for hard ground in mining, and No. 3 for slate and other similar workings. This powder is manufactured on a commercial scale at Oare, near Faversham, where a large number of military and naval officers, scientific and mining gentlemen assembled recently to inspect the process of manufacture, and to witness some experiments to test its power and safety.

The first point—the manufacture—proved very interesting, as it showed how that from a mere laboratory experiment, the cotton gunpowder had passed through many phases until it had become capable of production in commercial quantities. The initial process as shown to the visitors, consisted in mixing together nitric and sulphuric acid, in which the cotton is steeped, 1 lb. at a time, after having been hand-picked and further cleaned by being passed through a scutching machine, and afterwards washed and dried. After remaining in the acid for about four minutes, the cotton is withdrawn, and the surplus acid squeezed from it under hydraulic pressure. It is said to bring with it 20 lb. of acid from the tank, 12 lb. of which are pressed out, the remaining 8 lb. being abstracted from it in a centrifugal machine, in which 6 lb. form a charge. From the centrifugal machine the cotton is sent alternately to two steeping tanks and centrifugal machines, and after the second washing and drying it is passed through a pair of coarsely set rolls, and subsequently through a pair set more finely. The fibres have now become finely divided into particles of gun-cotton, and in this condition are subjected to a lengthened washing in a tank of aërated water, the air being forced through the mass of liquid pulp by a fan blast. From the aërating washer the gun-cotton—for such it now is—is run into settling tanks and afterwards partially dried, when it is taken to an incorporating mill, consisting of a pan and pair of edge runners, in which it is triturated in company with one or two other chemical substances, which complete the combination termed cotton gunpowder. It now only has to be dried, and this is effected in wire gauze-bottomed trays placed over a channel through which a current of warm air is driven. From the drying house the powder is taken to the cartridge-filling sheds, and is made into cartridges, which are packed in cases and conveyed to the magazine. The magazine is situated some distance from the works, and is zinc-roofed and surrounded by a broad moat; zinc was preferred for the roof under the belief that if an explosion were to occur, the zinc would volatilize instead of being blown about in fragments.

The second point—the experimental trials—proved no less interesting than the first, inasmuch as it showed how that from a comparatively unsafe and unreliable explosive compound—as the gun-cotton was when we first saw it some three years since—it had become an apparently safe and reliable blasting agent of great power. And this, we should here mention, is due to the pertinacity with which Mr. Mackie, the engineer of the company and manager of the works, and M. Faure, their chemist, have stuck to the task of developing the invention into its present practical shape. Not less credit is due to Mr. Trench, who has had the practical carrying out of the works under the above gentlemen. The first series of experiments were intended to illustrate the safety in transport and storage of the cotton gunpowder and included the lighting of cartridges by ordinary means, when they simply burned quietly away, and the ignition of others by a capped fuse, when they exploded violently. Some cartridges were then capped with dynamite detonators which previously had failed to explode the cotton powder, which, as a rule, requires a more powerful detonator of special make. Wednesday, however, being a show day, the dynamite detonators, possibly not wishing to be outdone by their special brethren, in each case exploded the new powder, a point, however, which is of no great consequence either one way or the other. In order to show that explosion would not follow upon conflagraiton, two barrels of the new powder were placed each in a roaring bonfire, and after a time the barrels were burned through and the contents blazed harmlessly away. An iron pile driver weighing half a ton was then allowed to fall 15 ft. on to a box containing 10 lb. of the powder in order to illustrate immunity from danger in such cases as railway collisions, which, so far, it did, as the box was smashed and the powder scattered around.

The second series of experiments illustrated the strength of the powder, and consisted first in placing a charge of 2 oz. in a bore hole made in a block of Kentish rag stone measuring 5 ft. by 3 ft. by 18 in., the explosion of the charge cracking the stone in all directions. Four steel ingots weighing 8 cwt. each were next laid in a pile with 2 lb. of the powder placed centrally between them. The explosion of the charges broke the ingots up and hurled the pieces to long distances. Other four ingots weighing 11 cwt. each were similarly treated with 2½ lb. of the powder with similar results. A cylinder of cast iron 2 ft. in diameter and 18 in. deep was charged in a central bore hole with 6 oz. of cotton gunpowder and fired, but the explosion only blew the hole through, driving a conical shaped piece out of the bottom. A 6 ft. length of 70 lb. steel rail was then laid on its side on bearings 4 ft. 6 in. apart, and in its groove ½ lb. of the powder was placed and tamped with clay. The explosion broke the rail into four pieces, throwing the two ends far apart. In military work the first illustration given was the cutting off a post of 12 in. by 12 in. timber—assumed to be a stockade post—with 2 lb. of the powder placed against its side. The application of the compound to land mines was shown by placing two boxes each containing 30 lb. of the powder in holes in the foreshore of the Swale—which flows by the company's works—covering them with 6 in. of sods and exploding them. The result in each case was the formation of a crater 22 ft. in diameter and 8 ft. deep, besides the demolition of some of the factory windows, a result, we need hardly say, which was more unexpected, than the other. To illustrate the statement that the powder could be exploded even when saturated with 20 per cent. of moisture, a box of the powder stated to be so saturated was placed on the beach and successfully exploded. The concluding experiment was the explosion of 50 lb. of cotton gunpowder suspended in the Swale in a case 10 ft. below water level. The explosion threw up a fine column of water some 200 ft. into the air, much to the satisfaction of the visitors, a satisfaction, however, not inferior to that afforded by the previous experiments, which demonstrated that a safe, handy, and powerful explosive was ready to be placed on the market. It has yet to undergo the test of time and experience in practical use, but from what we saw and heard of it on Wednesday there appears little reason to question its survival in these respects.

SCIENTIFIC SURVEYS.

From "Nature."

The almost universal idea in this country of what constitutes a Scientific Survey goes no further, we believe, than the departments of Topography and Geology, and, as we are a seafaring people, the Hydrography of our coasts. We daresay many of our readers will be surprised to hear that some whose opinions in matters of this kind ought to have great weight, deem any survey totally inadequate which does not, to a greater or less extent, include nearly every department of science What are the prevalent notions on the subject on the other side of the water, may be learned from a Report just issued on a proposed New Survey of the small State of Massachusetts.

Last year the American Academy of Art and Sciences presented a memorial to the General Court of the State of Massachusetts, urging the necessity for a new Scientific Survey of the Commonwealth. It is forty years since there was a survey of the State; that was the first public survey in the United States, and included not only topography and geology, but zoology, botany, and agriculture as well. The biological surveys were so well done that some of the reports are even yet regarded as standard works, but the advances in all departments during the past forty years have been so great, that practically a new survey is required.

The suggestion of the new survey came appropriately from the principal scientific body of the State, and it is gratifying to see that the Legislature have such a respect for its opinion as at once to take action upon the suggestion. The memorial of the Academy was referred to the Board of Education, a committee of which took the wise course of calling to their council the most eminent men of science in the State, who could aid them with their advice. The names of most of those who were called in to give the results of their study and experience are known to science all the world over; they are Professors B. Peirce, N. S. Shaler, and E. N. Horsford; President Clark, Dr. T. Sterry Hunt, Dr. Asa Gray, Dr. A. S. Packard, Mr. G. B. Emerson (who reported on the trees and shrubs in the former survey), Mr. Alex. Agassiz, Hon. Moses Kimball, Mr. C. F. Adams, Mr. S. H. Scudder, Mr. A. G. Boyden, and Mr. H. F. Walling.

The Report which has come to hand gives an account of the meeting between these eminent representatives of science, pure and applied, and the committee of the Board of Education. Each one freely expressed his opinion of the desirableness of the proposed survey, showed how it should be conducted so far as his own department was concerned, and pointed out the advantages which would certainly follow from a thorough survey. As might be expected, they are unanimously in favor of the proposed undertaking; and the immense advantages which were shown would accrue from it if carried out thoroughly in all departments, leave the State no alternative but to organize it as early as convenient.

A special committee from among the men of science named above—Messrs. Peirce, Sterry Hunt, Shaler, and Scudder—in their Report to the Education Committee recommend a scale of 1: 25000, or 2½ inches to the mile, as the scale which ought to be adopted for the survey; but this they do solely on the score of expense, admitting the superiority of the 6-inch scale. Prof. N. S. Shaler, in an impressive article in the March number of the *Atlantic Monthly*, strongly advocates the latter scale; for although the immediate cost would be at least double that of the smaller scale, still in the end it would be more economical; as, although the smaller scale would serve many useful purposes in the meantime, he declares it would be found that the survey would have to be repeated on the larger scale. We think the State of Massachusetts would be wise to profit by Mr. Shaler's hint, and accomplish the survey once thoroughly and completely on the larger scale, so that it would never require to be repeated. Indeed, the United States have had several lessons on this point; a considerable number of the States have been surveyed, but the surveys have all been more or less failures; there is not a single survey in this country," Prof. Shaler states, "which does not need at the moment to be done over again."

The practical advantages of topographical and geological surveys are so evident that it is unnecessary to point them out; no one, we presume, will deny that it is the interest and duty of every civilized country to obtain a complete and trustworthy knowledge of the extent, configuration, and composition of its surface. The important practical advantages which may result from a thorough geological survey has been well illustrated by a recent undertaking in America—the Hoosac Tunnel. It is Prof. Shaler's belief that "a due inspection of the surface of that ridge would have disclosed some of the difficulties encountered in the excavation of the tunnel, difficulties which would have been in a large measure avoided, had the engineers been forewarned. It does not seem too much to say that the cost of a complete survey, with a map on the scale of six inches to the mile, might have been saved by this easily gained knowledge."

But the State of Massachusetts has already had the wisdom to perceive that it is for the material advantage of the country that a knowledge of more than its topography and its geology should be easily accessible. To a thickly populated country, what can be of more moment than its hydrography, its water supply, which is also of so great importance in connection with manufacturers? In the proposed survey of Massachusetts a thorough knowledge of its hydrography will probably be considered as an indispensable part of the work. It seems almost a truism to say that in a country devoted to agriculture, an exhaustive scientific examination of soil would be a work of the greatest national advantage; such an examination has been to some extent made in Massachusetts, and the scientific men whose advice has been asked urge that it should be carried out over the whole of the State.

The practical advantages to be derived from a knowledge of the botany and zoology of a country, especially a country where agriculture is one of the staple industries, seem almost equally apparent. If our farmers were well acquainted with all the plants and insects and birds which annually destroy so large a quantity of the cultivated produce of the soil, and at the same time knew how to meet their ravages, the saving to the nation would be enormous. Dr. A. S. Packard estimates that in Massachusetts alone they lose every year, from insects and parasitic plants, 500,000,000 dollars; and that in one year alone they lost by the army-worm 250,000 dollars' worth of hay-crops. No wonder he says, "Certainly it will be a good thing to have a body of observers at work systematically, year after year, collecting information, which may be spread before the farmers of the State and others interested." In this connection the words of Mr. A. G. Boyden are worth quoting:—

"The relation of the animal to the vegetable kingdom is a most intimate one. In the cultivation of orchards, garden vegetables, and things of that sort, upon which we as a people depend a great deal, we have to contend continually with insects; if we could learn, therefore, the facts about the insects that are found in this State; if we knew how they were generated, how they grow, and what they feed on, we might do a great deal towards saving a large part of the crops that are now destroyed by them. For instance, the canker-worm comes periodically, and very few people know much about the habits of this insect. Very little is known about insects by people generally. They do not even know them by name. They do not recognize an insect in the three stages of its life. Every gardner, every orchardist, every person cultivating herbs, trees, or shrubs, needs this information. As has been said this morning, we have not the books to which we can go for help in gaining this information. . . . Mr. Emerson has given us an excellent book on the trees of the State, which is a very great aid, but in respect to the other matters of which I have spoken, we have very few such helps as are needed. It would seem, therefore, that a survey of this kind, in which scientific men were employed, who could, as they went over the different localities of the State, collect, incidentally, and without adding very much to the expense, the facts relating to these subjects, would be of great value."

The body of evidence contained in the Report before us seems to us to show clearly, what indeed is almost self-evident, that one of the first duties of a nation, from the lowest point of view of self-interest, is to obtain a complete scientific knowledge of its home and all that it contains; only thus can it be able to make the most of its natural resources.

While the great practical advantages of the survey were insisted upon, the gains to science and to education which would accrue from it were also brought prominently forward. Some important problems in science, it was shown, might be solved by a thorough geological and biological survey of Massachusetts; one of the most important of these is in connection with Cape Cod.

"Here, in Massachusetts," Prof. Shaler says, "you have certain peculiar questions connected with the distribution of animal life to the north and south of Cape Cod which offers one of the most remarkable illustrations of the variations in the distribution of animal life that is afforded anywhere in the world. The constant changes, as years go by, the influence of temperature on the distribution of animals, these are questions which can be investigated there. There is no question that Cape Cod is one of the great problems of Massachusetts, and it is a problem on which a large number of investigations should be hung. Prof. Peirce, who has carefully traced and grouped the facts connected with that part of the coast, will agree with me in saying that Cape Cod is the key-point; that geologically it is the most important point in Massachusetts, with regard to the agencies that have been at work in the creation of the soil, especially with reference to the glacial period, &c."

With regard to education, it was shown that in several ways this exhaustive survey would be of great value. It was proposed by some that the scientific students in the several colleges might with advantage to themselves be occasionally employed on the work, while they might be of some assistance to the survey-parties; this plan, if judiciously carried out, might indeed be of great service both to the students and to the work of the survey. Prof. Shaler pointed out that what he thinks the principal defect of the British Survey does not concern its work, but its effect upon British science. "It has not taken pains," he said—and we cannot take upon ourselves to judge of the justice of his statement—"to connect itself enough with the work of education in Great Britain; and the result is, as is admitted by some of the oldest geologists there, that there are few young geologists coming up in England at this time." This, if true, is certainly a great lesson for Massachusetts, as Prof. Shaler says; we hope, however, he has overstated the case, or at least that the supply of geologists in this country is not dependent on the Geological Survey. It was shown that in other ways a complete survey in all departments would be of the highest advantage in carrying on the practical education of the young in schools of all classes; and that from want of the results of such a survey, education was seriously hampered.

It will thus be seen that if in the course of years—for it is proposed to do the work leisurely and allow eminent scientific men to share in it as they can find opportunity—the people of Massachusetts do not have one of the most accurate and most complete surveys in the world, it will simply be because they are blind to their own real interests, which have so forcibly been brought before them by some of the most eminent of their scientific men, in whom the State is so rich. But as "the commonwealth of Massachusetts has not been wont long to weigh great advantages against small expenditures, so we may safely anticipate," with Prof. Shaler, "her speedy action."

Need we point any moral for ourselves from the liberal and comprehensive ideas which the comparatively small (its extent 7,800 miles, is only about that of Wales) and young State of Massachusetts has of what a survey of her territory includes? We have our topographical and our geological surveys, both doing excellent work, and both already productive of large practical and scientific results. But if we want to make the most of our small and over-crowded country; if we want, as we certainly should if we have our own welfare at heart, to have a complete knowledge of our country's resources, why should we stop short at topography and geology? Forty years ago Massachusetts showed itself to be far wiser than Britain is even now. Even then the little Transatlantic State saw it to be to its best advantage to know all about its soil and its natural products; we do not know that the question has ever been mooted in this country. A knowledge of what is being done on the other side of the water may give us a perception of our true interests, and our duty to ourselves and the world. To apply the words of Prof. Shaler: "Look at it as we may, measuring its immediate gains to our mines, our fields, our water-mills, to our cities in their water supply and sewage, to our railways and common roads, to the interests of each owner of an acre that is to be improved; or considering the remoter yet not less real economy which is found in increased knowledge of the Nature about us, and in the advancement of education, the reasons for this Survey are very strong."

The Moscow-Brest Railway has been doubly unfortunate lately. Its traffic manager has just had a severe reprimand inflicted on him, in the official organ of the Ministry of Roads and Ways, for what amounts to general negligence in the service of the line, and its main station, at Moscow, has just been destroyed by fire. Admiral Possiett is said to have decided on augmenting the railways to the extent of 6,500 versts, which, with those already projected, will give 8,000 versts to be constructed. The works will be divided into four classes, and commenced in the order of their relative importance. The first lines to be taken in hand will be those to Siberia, and to the coal-fields of the Don. The Russian correspondent of the *Standard* says that the vexed question as to the northern or southern route for the Siberian line is not yet settled, but there are many signs which show that the southern route will be preferred. The Society to aid the Development of Trade and Industry in Russia has lately devoted a series of sittings to the details of this important commercial question, and, after discussion, resulted overwhelmingly in favor of the southern line.

RECENT IMPROVEMENTS IN THE MANUFACTURE OF PEBBLE-POWDER.

By Major J. P. MORGAN, R.A., Assistant Superintendent, Royal Gunpowder Factory, Waltham Abbey.

"Journal of the Royal United Service Institution."

I HAD the honor of being asked last year by the Council of this Institution, to give a lecture on "pebble-powder;" but the subject—which is a very difficult and complicated one—at that time not appearing to me to have been thoroughly worked out in all its details, I begged to be allowed another year for further consideration. I may not even now be able to give a completely satisfactory solution of the whole question, but I hope to bring forward a good many facts connected with the manufacture of pebble-powder, and thus give a tolerably fair idea of the state of matters up to the present time.

The points to be attained, as is well known, in any improvements in the manufacture of powders, are an increased velocity of projectile, a diminished strain on the gun, and greater uniformity of results. It was the introduction of heavy and rifled guns, that drew attention to the importance of these points, and we accordingly find that as the size and precision of fire of guns have increased, the necessity for improved gun-powder has been felt in all countries. In a paper read here in 1871,* I entered very fully into the methods which have been used for determining the explosive force of gunpowder, showing that it is to Captain Rodman, of the United States Army, that we are indebted for having first taught us how the pressure of gunpowder may be measured in the bore of the gun in which it is fired. This is the only satisfactory way of solving the question, and we accordingly find that his experiments led to the discovery that the means of moderating the rate of combustion of gunpowder lay not only in increasing the size of the grain, but also in increasing the density. Thus originated the American mammoth and perforated cake powders, which have since found their way in modified forms into all countries where the art of powder-making has advanced. The prismatic powder, which has been adopted in Russia and Prussia, is derived from the American perforated cake, and the mammoth powder has appeared in Belgium as "*Poudre á gros grain*," and is slowly making its way into France, Italy, and other continental countries. It has been imported into England under the name of "pebble-powder."

As early as 1858, a Special Committee on gunpowder was appointed under the presidency of Colonel Askwith, then Superintendent of the Royal Gunpowder Factory, Waltham Abbey, and their investigations resulted first in the introduction of R. L. G., and afterwards in the recommendation of "pellet-powder" for heavy guns. In their final Report in 1866 they recommended that extensive and systematic experiments should be carried out with the latter powder. They also tried experiments with a pebble-powder which then went by the name of 2 A 4. It was made at Waltham Abbey, in imitation of the American mammoth powder, by breaking up press cake with copper hammers, and sifting the pieces between meshes of 1 and 2 to the inch. The effect of density in modifying the action of powder was overlooked, and this powder when fired in the B. L. guns was found not only to destroy the vent-pieces, but also to enlarge the chambers of the guns, the latter circumstance showing that the fault lay not in the guns but in the gunpowder. It differed from the American mammoth in one very important respect, being only 1.62 instead of 1.82, which is the American density for both cannon and mammoth powders. It is unfortunate that further experiments were not tried with higher densities, as it is probable that thus we should have had our pebble-powder much sooner than has been the case. The importance of density, however, was not at that time so well understood as it now is, and there appears to have been

* On "The Determination of the Explosive Force of Gunpowder," see Journal, vol. xv, page 312 *et seq.*

a bias on the minds of some of the members of the committee in favor of regular grains pressed separately in moulds, which process they considered also could be carried on more economically than the granulation of 2 A 4 powder, where there was a great amount of waste.

The introduction of the mercurial densemeter at a later period allowed the question of density to be more satisfactorily dealt with. This instrument was first designed in France, and was used for some time in the Chemical Department, Royal Arsenal, before it was introduced in the Royal Gunpowder Factory at Waltham Abbey in 1869.

The present Committee on explosives under the presidency of Colonel Younghusband, Superintendent, Royal Gunpowder Factory, Waltham Abbey, was appointed in 1869, and conducted an extensive series of experiments with various powders by methods similar to those used by Rodman, which led them to the conclusion that pebble-powder was better suited to the requirements of the service than pellet-powder. As it is also now very much easier and safer to manufacture, the change they recommended from pellet to pebble is not to be regretted. It is to the slow and steady progress in the manufacture of this powder that I propose to direct your attention this evening. In doing so, it seems to me that I shall be best able to acquaint you with the subject by giving a short historical sketch of the process as carried out at Waltham Abbey, and, as far as I know, by those merchants who have supplied pebble-powder under contract. You may depend upon the facts I adduce; but I may caution you against accepting too readily the conclusions I draw, because I know no subject where hasty conclusions are so apt to be overthrown as in the case with the manufacture of pebble-powder.

The first specification sealed to govern the manufacture was 16/5/70, the density being 1·8, the size of grain between $\frac{5}{8}$ and $\frac{1}{2}$ inch, and when fired in the 8-inch gun the velocity between 1420 and 1480 f.s., and the pressure in no case to exceed 20 tons in the bore of the gun, as indicated by the "Crusher" gauges in use by the Committee. Soon afterwards, however, it was found that there was a difficulty in maintaining the velocity, and the specification was altered as regards density, with a view to meet the requirements of the case, being lowered to 1.765 in August the same year. Some powder had been made having a density of 1.8, but it was kept in reserve, and afterwards mixed with pebble having a lower density, so as to give a mean of 1.765. The manufacture was continued at this density, and as the proof in the 8-inch gun was satisfactory, it was imagined no further difficulty would be experienced.

The method at first adopted of breaking up the press-cake into pebbles was the same as that described for producing the 2 A 4 grains, viz., the use of copper hammers. This is manifestly a very tedious and troublesome process. It is still, however, to be seen in operation at the Wetteren Factory, in Belgium, where the cake is first cut into strips by a sort of guillotine machine, and afterwards broken up in this fashion by means of wooden mallets in a hollow hemispherical bowl, into pebbles.

A system of chopping up the cake by means of copper knives very soon superceded the method of breaking up by hammers at Waltham Abbey. The cake was first cut up into strips by the knives, and these strips were again chopped across into pebbles by the same instrument. It was, of course, a tedious process, but it had the advantage of making little or no waste, and nearly the whole of the press-cake could thus be converted into grain.

A good many experiments were tried with a view to granulate the pebbles in the same way as ordinary powders, but all the attempts were very unpromising, owing to the irregularity of the grains and the great amount of waste. Messrs. Curtis and Harvey, however, produced a large proportion of their pebble-powder supplied by contract in this manner. They only, I believe, however, obtain about 30 per cent. of grain from their cake, and though this low percentage does not inconvenience them, inasmuch as they can find other uses for the small er grains, it would not do at a Government factory, where there is no other use to which they could be applied.

The chopping-knife was in operation for a considerable time, and turned out the whole of the pebble manufactured at Waltham Abbey from August, 1870, to May, 1871, during which time about 4,000 barrels of 125 lbs. each were manufactured and sent to Purfleet.

One man could thus cut about 150 lbs. a day, so that the granulation of pebble-powder at that time required the continual employment of nearly 20 men for the very small out-turn of about 100 barrels a week.

The following extracts from the proof books will show the nature of the powder manufactured at this time:

Brand of Powder.	Density.	Date of Experiment.	Number of Experiment.	Muzzle Velocity.	Pressures in Tons.		
					A.	B.	C.
15/10/70	1.761	27/10/70	357	1460	17.1	18.1	16.3
14/11/70	1.765	8/12/70	367	1446	18.1	18.0	15.6
31/12/70	1.757	1/2/71	389	1409	15.4	15.4	14.6
21/1/71	1.759	1/2/71	392	1409	12.6	13.1	12.1
3/2/71	1.761	20/3/71	408	1405	14.1	14.2	13.9
25/3/71	1.759	5/4/71	440	1406	15.5	15.0	14.8

It will be observed that there is a steady decrease in the velocity at proof. Some of the velocities are even lower, but these samples give an idea of the general average of the work produced at this time.

Meanwhile experiments were being carried on with a view to turn out pebbles in larger quantities and more economically than by the tedious process of chopping up with knives. My predecessor, the late Captain Smith, R. A., hit upon a plan which was very successful in doing the same sort of work.

This was by making a succession of knives come into operation one after the other, by being arranged longitudinally on the circumference of two long rollers.

The cake was thus very rapidly cut up into strips, but in putting the latter through the second time endways much time was lost, as each strip had to be picked up separately by hand before being put through. He contemplated having a second pair of rollers of the same description as the first, for the strips to pass through, but was unable to devise a method of conveying them from the first to the second pair of rollers, and so his plan for a time remained in abeyance.

Colonel Younghusband thought that the strips could be conveyed, as they passed the first pair of rollers, in succession to a second pair, which had the knives arranged circumferentially instead of longitudinally.

He found, however, that the strips would not drop horizontally on to the second pair of rollers, but that they dropped as often endways as sideways, and generally that they fell in all directions, owing to the uneveness of the press cake from which they were cut.

Mr. Pigou, of Pigou and Wilks, designed a very ingenious pair of rollers, which performed the work of cutting up the cake into pebbles in one operation. Both rollers were identical and had the knives arranged, longitudinally nor circumferentially, but spirally, at an angle of 45° round the surface. The knives thus crossed each other perpendicularly at the cutting points, and very tolerable granulation was effected. The pebbles, however, were very irregular in shape, and by no means so cubical as those cut up by knives.

It had hitherto been supposed that, the more uniform the size and shape of the grain, the better would be the results at proof; but while Waltham Abbey pebble seemed to be failing at proof, Mr. Pigou's pebble gave very good results, as shown by the following experiment:

Powder.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
Lot 826.......	1.765	28/3/71	428	1460	16.5	16.4	15.8

I have stated my intention of describing the manufacture of pebble-powder as I have learned it myself, and I may here say that this was the position of affairs when I was appointed Assistant Superintendent in succession to Captain Smith. I hope I have succeeded in convincing you that the manufacture of pebble-powder is a great mystery; at least so it appeared to me.

It seemed a tolerably easy matter to turn out powder, but to make it produce the desired results in the 8-inch gun, so as to pass the specification, was quite another affair.

I suggested to Colonel Younghusband that it seemed very probable that the fact that Mr. Pigou's sample consisted of irregularly shaped grains was the reason why he obtained a better velocity than could be obtained with the Waltham Abbey regular cubes, because the irregularly shaped grains would present larger surfaces for initial ignition. It would not do to use small grains, because they would interfere with the passage of the flame in igniting the charge; but there could be no objection to large irregularly shaped grains. Colonel Younghusband tried the experiment, and used the larger rollers in an ordinary granulating machine to break up press cake into irregular grains. This was mixed with knife-cut pebbles, and, on firing a sample of the ordinary work in comparison, the following result was obtained:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
25/4/71	1.770	2/5/71	483	1399	16.9	16.6	15.6
25/4/71 Granl. P.	—	2/5/71	485	1436	19.4	19.3	19.7

It seemed to me that, in Colonel Younghusband's machine, the strips might be made to rectify themselves by being allowed, in the first instance, to drop on a canvas band, which, as it traveled, would convey each strip forward so as to allow the next to drop behind it, and afterwards convey the strips in succession in the proper position to pass through the second pair of rollers.

This plan was tried, and was found to answer quite successfully. A very simple machine thus constructed was in operation from the end of May, 1871, to March, 1872. The following is the proof of the first sample turned out by this machine:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
19/5/71	1.768	24/5/71	534	1475	20.9	20.3	20.0

It will be seen that the velocity and pressure are both high, which is no doubt due to the fact that the pebbles turned out by this machine were smaller than the hand-cut pebbles. The results obtained, however, seem to meet the requirements of the case, especially as the out-turn of the machine was only about 40 barrels a day. The capabilities of the factory in the other processes of manufacture are much greater, and so the chopping process was continued, and the pebbles produced by both processes were mixed together and the total out-turn increased from about 100 barrels to nearly 300 a week.

Colonel Younghusband tried an experiment to compare directly the work produced by hand-cut and machine-cut pebbles, not only with the ordinary work of the factory, but also with work which had been milled with an increased amount of moisture in the charges, with the following results:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
OK. 2/6/71	1.768	10/6/71	549	1440	19.4	19.8	18.6
HK. 2/6/71	1.782	10/6/71	550	1444	16.7	15.6	16.3
OM. 7/6/71	1.787	16/6/71	570	1445	19.7	17.4	16.6
HM. 7/6/71	1.782	16/6/71	579	1437	19.6	18.8	18.0

It will be seen that there is not very much choice, but that on the whole the charges worked "heavy," or with the increased percentage of moisture, produce the best results. The more moisture in the powder the less is the danger arising from an explosion in the mills, and the charges were accordingly afterwards worked heavy. All stovings are proved in the 8-inch gun, and those which meet the required tests are at once "branded," and passed into the service.

The others are mixed in a manner calculated to produce the required results. The velocities and pressures obtained at proof were always a matter of considerable uncertainty. I may compare our various stovings to different vintages of wine. We had an uncertain control over our stovings, but after proof we were able within certain limits to produce any brand required.

A regular systematic mixing had to be established so as to work off and send away the manufactured powder as speedily as possible after proof. At first the stovings were mixed, in a rough and ready way, by two men each taking a barrel and alternately pouring a small portion of the contents into another barrel, but very soon a more methodical and satisfactory plan was established.

It appeared to me that, in order that our mixing should be a success, some plan must be adopted of securing that each stoving itself should be perfectly uniform. It appeared vain to attempt to work to densities, for, from the samples already given, it will be seen that density taken alone is no criterion of what may be expected at proof. A mechanical system of mixing seemed to promise the best results, and this plan was adopted. In order to do this with as little trouble as possible, advantage was taken of some of the processes of manufacture.

A glazing as a rule consists of four large barrels or churns, each of which contains about four small barrels of powder. As these churns revolve at 37 revolutions a minute for four hours, it may safely, I think, be assumed that the contents of each churn are well and uniformly mixed. It by no means follows, however, that the contents of one churn are of the same character as those of the others.

The next process is the stoving, and advantage is taken of the method of setting the stove to make the whole of one glazing perfectly uniform. The powder is set in trays, each tray containing four bowlfuls, or about 16 lbs. In filling a tray, a bowlful is taken from each churn, and thus every tray of a glazing contains exactly the same powder. The glazings are marked off separately in the stove. After stoving, the powder is finished by being revolved about 20 minutes in reels which contain four barrels each, and, as the stove contains four glazings, this gives the required facility for making the whole contents of a stove uniform, because into each reel can be put one barrel from each glazing. I know no process which has been attended with greater certainty in producing uniform powder than this system of mechanical mixing. It gives no extra work, and requires only a little care and attention on the part of the workmen.

Though each stoving, however, is perfectly uniform, it will be seen by the following proofs that different stovings are by no means of the same character. These stovings are selected as giving as near as possible an average of the work turned out, some being higher and some lower as regards velocities and pressures.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26/6/71	1.772	14/7/71	648	1461	21.4	21.6	19.4
30/6/71	1.792	5/7/71	627	1332	11.5	11.1	21 0
10/7/71	1.792	14/8/71	59	1385	14.4	14.2	13.8
29/7/71	1.763	7/8/71	38	1507	22.8	20.7	20.0
9/8/71	1.758	18/8/71	80	1400	14.6	15.0	14.4
18/8/71	1.776	25/8/71	101	1442	17.8	17.5	16.6
28/8/71	1.777	6/9/71	134	1408	16.3	16.2	15.0
1/9/71	1.784	6/9/71	137	1358	13.3	13 4	13.4
26/9/71	1.762	9/10/71	225	1436	18.4	18.3	17.1
3/10/71	1.753	13/10/71	253	1440	17 2	17.2	16 7
18/10/71	1.765	27/10/71	298	1438	18.5	19.2	17.1
1/11/71	1.768	9/11/71	336	1428	16.1	16.3	16.4
13/11/71	1.736	23/11/71	375	1469	17.4	18.4	17.8
16/11/71	1.735	23/11/71	377	1512	19.9	21.2	21.0
17/11/71	1.736	23/11/71	378	1534	25.1	24.9	23.5
17/12/71	1.750	15/12/71	459	1438	14.8	16.2	16.1
15/12/71	1.750	2/1/72	501	1396	13.3	12 3	12.8
28/12/71	1.755	3/1/72	524	1391	15.1	14.3	14.4

It will be observed that, though a good many of these stovings are within the limits of the specification, some are very much too low in velocity, while others are too high, both as regards velocity and pressure. Those stovings which were too high in velocity or pressure were mixed with others which were of low velocity and pressure, so as to give a mean result within the specification. This was attended with little inconvenience, as long as the mean results of proof fell within the specification, but it was rather troublesome when there was a long series of proofs of the same character. Some of the proofs, it will be observed, are either exceptionally high or exceptionally low. With regard to stoving, 30/6/71, I find the following note in the proof-book, in Colonel Younghusband's handwriting:—"1,000 grs. sample of this powder was dried by Mr. Abel for five hours, at 200° Fah., resulting in a loss of 0·33 per cent., proving that the very low velocity was not caused by moisture."

Stovings 16 and 17/11/71 call for special remark. Every inquiry was made as to the possible cause of the low densities and high pressures and velocities, but nothing could be traced, excepting that the chief foreman believed that the charcoal had been overburnt. As this fact at the time was thought calculated to produce the opposite effect, the real cause appeared to be a mystery.

The change from the old to the new gun does not appear to make much difference, as it will be observed that there are low velocities with the new as well as with the old. This latter point was not, however, left purely to speculation, for Colonel Younghusband tried identical samples in both guns, with the following results:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26/6/71........	1.772	14/7/71	647	1460	21.5	20.6	18.5
Ditto...........	Ditto	Ditto	648	1461	21.4	21.0	19.4
5/7/71..........	1.789	12/7/71	638	1368	13.6	13.5	13.0
Mean of above mixed, 2 to 1..	....	....	...	1436	18.8	18.4	17.0
Ditto, 2 to 1 in old gun......	....	14/7/71	650	1420	18.9	17.6	16.5
			652	1450	19.5	19.5	18.1
			653	1454	20.4	19.8	18.7
Ditto, 2 to 1 in new gun.....	...	31/7/71	7	1439	17.6	17.2	16.3
			8	1453	18.7	18.9	17.5
			9	1449	19.8	19.8	18.1

The plan of mixing the stovings, as I have stated, was at first by hand, but toward the end of 1871, a four-way hopper was made, which materially assisted this process. Sometimes the stovings were mixed two and two, and sometimes four and four, according to the circumstances of the case.

I have brought the manufacture at Waltham Abbey, down to the end of 1871, and it will be observed that the old tendency to low velocity again begins to manifest itself; and, as this tendency appeared on the whole rather to get worse than better, it began to become troublesome. Not only at Waltham Abbey did it show itself, but in nearly all the powder sent in by the merchants by contract. Lot after lot manufactured by Messrs. Curtis and Harvey, and by the Kames Company especially, showed the same failing; and the question of the manufacture of pebble began to look serious.

The new year, however, introduced a new era. A sudden fit of inspiration seized Colonel Younghusband, and he ordered two samples to be restoved. Behold the result:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
10/1/72	1.765	24/17/2	605	1398	15.8	15.5	14.8
Ditto re-dried	....	31/17/2	677	1455	20.9	20.3	18.5
12/1/72	1.763	24/17/2	606	1367	13.8	13.8	13.8
Ditto re-dried	....	31/17/2	678	1418	15.6	13 6	14.6

It was a great relief to have discovered the reason at last. Doubtless some will think it was very foolish not to have discovered it sooner; but I hope they will suspend their judgment till they have heard the whole state of the case. Meanwhile I will observe that the cause had been suspected, and, as I have stated, a sample sent to the Chemical Department for analysis, showed a very small loss of moisture. The powder had received the usual amount of stoving. But, what is of more importance is, that when the discovery was communicated to the merchants, with a view to assist them out of their difficulties, one and all refused to believe it.

At Kames an experimeat was made to test the matter roughly, by weighing a large sample before re-stoving, and weighing it again afterwards, and, as only a slight difference of weight was detected, it was concluded that the fault of Kames' powder did not lie in its insufficient drying. An experiment was afterwards made at Waltham Abbey, with some of Kames' pebble, which partly bears out the result. Two samples were re-stoved, and fired as follows:

Brand of Powder.	Density.	Moisture.	Experiment.		M. V.	Pressure.		
			Date.	No.		A.	B.	C.
Lot 86..........	1.772	1.17	21/5/72	964	1338	16.1	16.1	14.8
Ditto, re-dried.	.....	.898	7/6/72	1030	1394	19.3	17.6	17.0
Lot 97	1.755	1.14	21/5/72	968	1336	16.2	16.4	15.0
Ditto, re-dried.	.....	.816	7/6/72	1031	1379	18.2	18.5	15.8

It will be observed that in the original samples there is no excessive amount of moisture, but rather under the normal amount if anything, and the re-dried samples may be considered over-dried.

The discovery of the great effect of moisture on velocity and pressure opened up a very large question, and threw discredit to some extent on all the experiments which had hitherto been made, seeing that it could not be told to what extent all the results had been vitiated by an unknown amount of moisture which existed in the samples fired. It at once explained why there had been so much low velocity powder a year before, and there can be no doubt that, had the reason been known in time, it would have been better to have re-dried some of the powder which had been mixed.

The manufacture continued as before, with varying results; sometimes the proofs were right, and sometimes they were too low, in which case they were re-dried, or mixed with others that were too high.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
8/2/72	1.756	15/2/72	710	1427	18.8	17.5	16.5
21/2/72	1.754	29/2/72	739	1478	17.9	18.2	17.3
4/3/72	1.762	7/3/72	778	1389	16.4	15.6	15.8
Ditto, re-dried	....	13/3/72	...	1466	18.1	18.6	18.0
23/3/72	1.762	8/4/72	900	1430	20.3	19.1	17.8

The last sample, it will be observed, shows a falling off in the powder, and the reason is to be explained as follows. A new machine on Colonel Younghusband's principle had been made, and had just then come into operation. It turned out such a large quantity of pebble that we could now dispense with the more expensive process of cutting by knives. The machine was calculated to give pebbles as large as with the knives, but evidently there was a fault somewhere. On examination I found that there were a great number oi flakey pebbles, of the description of cubes, divided down the middle. They thus were in length and breadth of the proper dimensions, but in thickness only half of what they ought to be. This I considered to be due to the faulty principle of the second pair of rollers, which did not allow of the strips extending outwards, as they were being cut. Though they were very detrimental to the proof of the powder, they could not be removed by the ordinary method of sifting. I succeeded in removing them, however, by the device of an oblong mesh.

When being sifted, the flakey pebbles tilted on their edges, and passed through while the ordinary pebbles were retained. It was found that the system of re-drying was rather troublesome, as it occupied the stoves frequently, when new powder was required to be dried; and, as 36 hours' drying could be given without extra inconvenience, the time of drying was increased on 1st April, 1872, to 36 hours, at the old temperature of 125° Fah. The following are some of the proofs:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
12/4/72	1.756	19/4/72	815	1428	17.6	18.2	16.3
22/4/72	1.752	26/4/72	923	1455	21.8	21.8	19.6
10/5/72	1.772	17/5/72	937	1408	15.2	15.3	14.8
Ditto, re-dried	....	29/5/72	1002	1507	21.6	21.2	17.7
13/5/72	1.777	17/5/72	940	1452	15.3	14.9	14.1

The last shows a considerable improvement over the others, being due to a great extent to the fact that a sifting apparatus, of the nature described, was now erected on the machine, so as to sift the pebbles rather severely, by taking out all the small and flakey specimens. This materially reduced the percentage of finished pebbles obtained from it; that, however, is not to be considered in comparison to the improvement produced in the powder.

I had all along been favorable to the principle of the other machine, proposed by Captain Smith, and had for some time, after a good deal of trouble and contrivance, got a design ready, by which the strips could be conveyed from the first to the second pair of rollers. When Colonel Younghusband found, therefore, that the percentage of pebbles produced with his machine was only about 60 per cent., I obtained his permission to have an experimental machine made according to my design.

It will be observed that the difficulty consists in conveying the strips, which fall in regular succession, from the first to the second pair of rollers, so that they not only shall not inconvenience each other, but also shall change their direction from moving sideways to a motion endways. This I accomplished by allowing the strips to fall upon a board, over which a succession of strips of wood were moving sideways, and scraping along the surface. Each strip fell into a space between two strips of wood, and was carried sideways along the board. When the first strip got to the end of the board, it dropped over on to a band passing below in a direction at right angles, and was thus conveyed endways to the second pair of rollers. It is manifest, if the board remained stationary, the second strip would drop over on to the top of the first before it had time to clear out of the way. To prevent this the board was made to move backwards so that the second strip, instead of falling on the top of the first, fell along side it, and slightly in arrear, and so on with the next and the next, till the board had moved as far back as could be allowed. The direction of the board was then suddenly changed and it moved forward in the direction of the strips of wood and at the same rate, so as to form a false bottom to the compartments which contained the strips of powder. When the board had arrived again at the original position, it again suddenly changed its direction and the motion proceeded as before. The method of changing the direction of the board was by attaching it to an endless chain which passed over two smal pulleys. Thus the direction was reversed every time of passing over a pulley.

It will be observed in the last samples of firing given, that the density has increased. Of course it was at once apparent, if the fault of low velocity was due to the moisture, there was no need to attempt to meet the case by working to the low limits of density, and the density was therefore increased. It was found, too, that even 36 hours' drying at 125° F. was not sufficient, and on the 1st June the temperature of the stove was increased to 135° F., for 36 hours, with the following result. The moistures are given at the same time to serve as a guide, if possible, to what may be expected at proof :

Stoving.	Density.	Moisture.	No. of Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
4/6/72	1.781	—	—	12/6/72	1034	1450	16.4	16.8	16.0
1/7/72	1.780	—	—	12/7/72	1109	1465	18.2	18.9	17.9
6/8/72	1.784	.93	—	15/8/72	1200	1447	17.5	19.2	16.8
21/8/72	1.781	1.03	—	13/9/72	2	1493	20.8	19.8	18.0
2/9/72	1.779	.9	—	4/10/72	37	1494	19.7	18.7	17.1
3/9/72	—	—	—	4/10/72	39	1492	17.1	15.9	16.4
1/10/72	1.777	1.44	80	9/10/72	63	1491	18.3	17.4	17.1
4/11/72	1.782	1.38	80	8/11/72	110	1452	16 4	16.4	16.1
22/11/72	1.781	1.57	70	2/12/75	143	1494	18.5	18.8	18.0
4/12/72	1.779	1.34	72	13/12/72	170	1475	18.6	16.2	16.9
14/12/72	1.772	1.33	76	24/12/72	187	1541	19.7	19.1	19.4

I have brought down the manufacture to the end of 1872, and I think it will be admitted that there is considerable improvement on the state of matters which obtained a year before. Not only has the velocity been very much increased, but the pressures have been very considerably reduced. This latter point is mainly due to the increase in the size of the pebbles. Instead of being about 140 to a pound, they are now between 70 and 80, as shown by the column of figures. It will be observed that, with the introduction of a new proof gun, there is a considerable rise in the average velocity. This is, no doubt, due to the fact that the old gun had fallen off to some extent by the wear of the bore. It is not possible exactly to say how much, but evidently it is some 30 or 40 feet in 1,200 rounds. Stoving 3/9/72 is the first sample with the machine I have described as worked out by myself on Captain Smith's principle. It not only gave much better pebbles, but a much larger percentage—about 80 per cent. This machine has ever since continued in constant operation without mishap, and has done the greatest amount of the work of granulation or pebble-cutting. The sifting arrangement in use with Colonel Younghusband's machine was an ordinary shaking screen, but it was found that the mesh for taking out the small and flakey pebbles was apt to choke up and interfere with its proper action. One of the foremen of the Machinery Department suggested that a reel would be more suitable. This was applied to my machine with the oblong mesh described, and has been found to work very satisfactorily. A reel of the same sort is now being fitted to Colonel Younghusband's machine.

[TO BE CONTINUED.]

THE CHEMICAL CHANGES ACCOMPANYING THE SMELTING OF IRON IN BLAST FURNACES.

BY DR. C. R. ALDER-WRIGHT, F.C.A.

Proceedings before the Royal Institution.

NOTWITHSTANDING that the operation of iron-smelting is one dating from a very early epoch, and in spite of its magnitude at the present day, and the consequently numerous series of observations and experiments made thereon by various chemists, it is nevertheless true that until recently our knowledge of the chemical changes which occur during the process was extremely limited.

It will not be necessary for me to-night to enter into any detailed description of the apparatus and machinery now in use in this manufacture; the blast furnace, as you are all aware, is virtually a gigantic vertical tube into the top end of which the materials used are continually inserted; these consist of the ore to be smelted, the fuel, and lime or lime-stone as a flux. At the lower end of the tube air usually heated to 300°–500° is continually injected by a blowing engine through nozzles termed *tuyeres*, whereby the fuel is burnt and the necessary heat generated: the earthy materials of the ore and the lime of the flux unite, forming a fusible "slag," which is continually drawn off at the base, whilst the molten reduced iron accumulates below the slag, being specifically heavier, and is drawn off from time to time into moulds of sand, when it constitutes the pig iron of commerce.

Ordinarily the air injected, or "blast," is previously heated by passing through tubes of iron or piles of brickwork, themselves heated by the combustion of the waste gases that escape from the furnace itself; to collect these, the top of the furnace is closed by a bell-shaped valve which serves for the introduction of materials when open, but which when closed compels the gases to issue through an orifice in the side of the furnace near the top, whence they are led away through pipes to the heating stoves, furnaces of boilers, &c.

The nature of the ore used necessarily exerts a great influence on the chemical changes that take place; the following Table indicates the general composition of several of the chief descriptions of ore used. In some instances the iron exists naturally as ferric oxide; in other cases chiefly as ferrous carbonate.

	Hæmatite.	Magnetic Ore.	Spathic Ore.	Clay Ironstone.	Brown Ore.
Fe_2O_3	90–100	30–70	0–3	0–3	40–70
FeO	....	13–33	36–50	35–55	0–5
Al_2O_3	0–2	0–5	0–2	1–7	1–7
CaO	0–3	0–5	0–4	1–14	1–7
MgO	0–1	0–2	0–4	1–9	0–2
MnO	0–1	0–1	1–25	0–2	0–3
SiO_2	0–10	0–10	0–5	2–17	0–3
CO_2	0–1	0–10	37–42	22–37	1–35
P_2O_5	0–1	0–2	trace	0–2	0–5
SO_3	0–1	trace	"	0–3	0–2
H_2O	0–1	0–4	...	0–1	trace
					6–18
Essential Composition....	Fe_2O_3 with little or no earthy matter.	Fe_2O and FeO with earthy matters.	$FeCO_3$ and $MnCo_3$ crystalline.	$FeCO_3$ and much earthy matter.	Hydrated Fe_2O_3 and earthy matters.

When ferrous carbonite constitutes the ore used, the smelting process is usually facilitated by submitting it to a previous calcination in a kiln like a lime-kiln, whereby the ferrous carbonite becomes transformed into ferric oxide; when, however, the carbonate is not calcined before use, it speedily loses the carbon dioxide present therein, leaving behind an oxide of iron; this occurs in the top portion of the furnace, so that virtually the ores used may be regarded as consisting essentially of some form of iron oxide, with a varying amount of earthy matter, of variable kind intermixd therewith.

The fuel used is ordinary coke or charcoal; when, however, raw coal is employed, it is completely coked in the top portion of the furnace, so that the fuel burnt at the tuyeres is invariably carbon.

As the blast enters the furnace it comes in contact with a mass of incandescent carbon, whereby its oxygen is firstly converted into carbon dioxide, and nextly into carbon oxide, the nitrogen for the most part remaining unchanged; not impossibly, a good deal of the carbon is burnt directly to carbon oxide, without passing through the intermediate stage of carbon dioxide; any moisture present in the blast is similarly converted into a mixture of carbon oxide and hydrogen; the amount of the latter necessarily varies with the hygrometric state of the atmosphere. Although hydrogen is a powerful reducing agent, the influence of the small quantity present in the blast-furnace gases appears to be practically *nil:* the gases issuing at the top of the furnace contain on an average about as much free hydrogen as is brought in by the blast, whence it is evident that the hydrogen has contributed little or nothing to the reduction of the ferric oxide; and again, practical experience shows that the more moisture enters the furnace at the base, the more fuel is requisite to do the work, *i. e.* the development of hydrogen is injurious to the action rather than auxiliary.

What I shall have the honor of bringing before you to-night is the history of the changes that occur as the mixture of carbon oxide and nitrogen formed in the vicinity of the tuyeres rises through the furnace. This action has usually been described hitherto as a very simple one; the carbon oxide being viewed as simply removing the oxygen from the higher oxide of iron, forming successively a lower oxide and metal, carbon dioxide being evolved in accordance with equations (1) and (2), *infra.*

TABLE of CHEMICAL CHANGES taking place in different parts of the BLAST FURNACE.

[A] Reduction of higher oxide to lower oxide and metal by gaseous carbon oxide.

(1) $Fe_xO_y + CO = Fe_xO_{y-1} + CO_2$
(2) $Fe_xO_y + yCO = x\,Fe + yCO_2$

[B] Oxidation of metal to lower oxide and higher oxide by carbon dioxide.

(3) $x\,Fe + yCO_2 = Fe_xO_y + yCO$
(4) $Fe_xO_{y-1} + CO_2 = Fe_xO_y + CO$

[C] Reduction of carbon oxide to carbon.

(5) $x\,Fe + yCO = Fe_xO_y + yC$
(6) $Fe_xO_{y-1} + CO = Fe_xO_y + C$

[D] Reaction of reduced carbon on iron oxide forming carbon dioxide.

(7) $2\,Fe_xO_y + C = CO_2 + 2\,Fe_xO_{y-}$
(8) $2\,Fe_xO_y + yC = yCO_2 + 2x\,Fe$

[E] Reaction of carbon dioxide on reduced carbon.

(9) $CO_2 + C = 2\,CO$

The changes that really take place are, however, much more complicated; it is true that these reactions do take place, but firstly carbon dioxide has a tendency to act on metallic iron, re-forming an oxide, and re-producing carbon oxide by reactions that are just the converse of (1) and (2), *viz.* in virtue of equations (3) and (4).

Nextly, metallic iron acts on carbon oxide, setting free carbon and forming successively a lower and a higher oxide in virtue of equations (5) and (6).

Again, the carbon deposited in virtue of reactions [C] reacts on the higher oxides of iron, producing lower oxides and metal, with evolution of carbon dioxide, in accordance with equation (7) and (8). And finally, carbon dioxide reacts on the deposited carbon, giving rise to the formation of two proportions of carbon oxide in virtue of equation (9).

Changes [A] and [D] may be referred to as *iron-reducing*, [B] and [C] as *iron-oxidizing:* changes [C] may be termed *carbon-reducing*, [D] and [E] *carbon-oxidizing.*

At any given point in the blast furnace all these chemical tendencies are at work simultaneously with more or less vigor according to circumstances; the action actually taking place at this point is, therefore, that due to the single resultant of all the multifarious forces at work; before, therefore, it is possible to enter into any explanation of the chemical changes occurring in the furnace itself, some knowledge must be gained of the relative magnitudes of these several forces. Considerable additions to our knowledge on these points have recently accrued, chiefly through the labors of I. Lowthian Bell, Esq., M.P., with whom I had the pleasure of co-operating in his researches.

As regards tendencies [A]. Although carbon oxide exerts no action on ferric oxide at ordinary temperatures, yet its influence is appreciable at temperatures far below the limit of the mercureal thermometer; the precise point at which the action commences varies with the physical condition of the ferric oxide; thus the following Table illustrates this point:

TEMPERATURE at which CARBON OXIDE begins to reduce FERRIC OXIDE.

Substance.	Minimum Temperature at which Carbon Dioxide is formed.	Temperature at which action is well marked.
	°	°
Precipitated by ammonia	141	149
Calcination of ferric nitrate	145	154
Average calcined Cleveland ironstone	199	210
Ditto, more highly calcined	200	206
Calcination of ferrous sulphate	208	216
Pumice-stone soaked in ferrous sulphate solution and calcined	211	227

The fact that the action is perceptible at so low a temperature may be conveniently illustrated by passing a current of pure carbon oxide over precipitated ferric oxide in a flask heated to 150° in a paraffin bath, and passing the gases subsequently through baryta water, when the formation of a turbidity denotes the production of carbon dioxide. (*Experiment performed.*)

It is noticeable that a specimen of ferric oxide that has been already slightly reduced in this way is first acted upon only at a higher temperature than that required in the first instance.

As regards equation (2.) it may be remarked that it is impracticable to reduce *the whole* of any sample of iron oxide by means of gaseous carbon oxide at any temperature short of a white heat; in fact, metallic iron decomposes carbon oxide, becoming itself more or less oxidized at all temperatures below this in virtue of equation (5).

In reference to the converse changes [B], the oxidizing effect of carbon dioxide on iron is scarcely appreciable at a temperature of 300°, but it is noticeable at 400° and upwards, being very considerable at about 600°: this may be illustrated by passing a current of carbon dioxide over fragments of metallic iron in a tube heated to a bright red heat, when much carbon oxide is evolved, so that the issuing gases may be inflamed. (*Fxperiment performed.*)

The physical condition of the iron employed necessarily exerts a considerable influence on the rapidity of the reaction, the more finely divided the metal, the more energetic being the action; thus pyrophoric iron is readily acted on by the air at the ordinary temperature, whilst more massive fragments of metal are unaffected under the same circumstances.

It is noteworthy that carbon dioxide is not capable of acting on all metals alike in this way. Copper, for instance, is unaffected at a red heat or upwards by carbon dioxide, whilst nickel and cobalt are oxidized with the production of carbon oxide, the change, however, taking place with less ease than with pure iron. The following Table illustrates this point.

COMPARATIVE ACTION OF CARBON DIOXIDE ON IRON, NICKEL, AND COBALT, at about 600°.

Iron	100
Cobalt	44
Nickel	11

Iron first begins to act	...	below 420°
Cobalt " "	....	about 550°
Nickel " "	....	above 550°

The consideration of the causes that lead to the possibility of the occurrence of the inverse reactions [A] and [B], and the different behavior of iron and copper towards carbon dioxide, introduce us to some general principles in chemical dynamics. Whenever a body unites with oxygen, heat is evolved; thus the following Table illustrates the quantity of heat produced by the union of 16 parts by weight of oxygen with various substances, the materials and products being all viewed as being examined at the constant temperature 500° C.

The numbers are calculated from the so-called "heats of combustion" of the bodies (at 15°) by means of the formula.

$$H_{500}=H_{15}+h_1+h_2-h_3,$$

where H_{500}=the heat of combustion at 500°.

H_{15} = " " 15°.

h_1 =the heat required to raise the combustible from 15° to 500°.

h_2 =the heat required to raise the oxygen through the same range.

h_3 =the heat required to raise the product of combustion through the same range.

Combustible.	Product of Combustion.	Kilogramme heat units evolved at 500°.
Iron	Magnetic (and probably any other) oxide*	66.7
Carbon oxide	Carbon dioxide	68.8
Carbon	Carbon oxide	27.4
Carbon	Carbon dioxide	48.1
Hydrogen	Steam	58.9
Copper	Cuprous / Cupric oxide*	37.6

The evolution of heat during these actions may be exemplified by sprinkling iron filings into a large gas-blowpipe flame, when a brilliant shower of sparks is produced, heat and consequently light being developed by the oxidation of the iron. (*Experiment performed.*) Similarly by burning carbon oxide at a jet through which a stream of oxygen can be forced, a blowpipe flame is produced equal in heating power to the oxy-hydrogen flame, and like it capable of igniting lime, and thereby giving off a bright light, melting platinum, steel, &c., &c. (*Experiment performed.*) Although carbon oxide actually gives out more heat than hydrogen in uniting with a given weight of oxygen (68.8 kilogramme units as against 58.9 when the action takes place at 500°), it is nevertheless much more difficult to obtain the same calarofic effects from a carbon oxide-oxygen flame than from an oxydydrogen flame. With a small flame, platinum may be readily fused and lime heated to intense brilliancy with either; but the

* When a body forms more than one *solid* oxide corresponding to a class of stable well-defined salts, the heat produced for a given weight of oxygen consumed is identical with each oxide; this is not the case when *gaseous* oxides are formed as with carbon; nor even when solid oxides are formed when they do not correspond to classes of stable well-defined salts, *e.g.* some of the oxides of manganese.

latter gives a much more compact, and therefore hotter, flame when larger amounts of gas are used: the comparative slowness with which the carbon oxide oxidizes is illustrated by the circumstances that a jet of this gas issuing under some slight pressure from a narrow orifice will not continue to burn in the air, the flame as it were blowing itself out; whilst a jet of hydrogen or of coal-gas burns readily under the same circumstances.

It seems to be a general rule that no reaction of replacement coming under the general form

$$x + y z = y + x z$$

can take place if the reaction is attended with any considerable absorption of heat; *i.e.* the heat given out by the substances x and y, in uniting with the same weight of z, must either be approximately equal, or else that given out by x in uniting with z must be greater than that evolved by y in combining with z. Some few exceptions to this rule are known, notably reactions [D] and [E]: generally, however, the converse is the case, *i. e.* in reactions of this class there is usually an evolution of heat.

Now copper and carbon oxide are not thermally equal as regards combination with oxygen; the latter evolves nearly double the heat given out by the former in uniting with a given weight of oxygen: hence the action of carbon oxide on copper oxide, producing metallic copper and carbon dioxide, must be attended with a large evolution of heat; thus at 500°:—

Heat produced by oxidation of carbon oxide to dioxide	+ 68.8
Heat absorbed during the reduction of copper oxide	— 37.6
Heat evolved	+ 31.2

Carbon oxide, therefore, reduces copper oxide to metal, forming carbon dioxide in accordance with the above rule; whilst the converse reaction, *viz* oxydation of metallic copper by carbon dioxide and conversion of the latter into carbon oxide, does not take place, as it would be attented with a large absorption of heat *viz.* 31.2 kilogramme units.

The evolution of heat during the reaction of carbon oxide on copper oxide, may be readily illustrated thus:—A tube filled with lumps of copper oxide is heated to a temperature short of visible redness, and a stream of carbon oxide is passed through it; the copper oxide immediately begins to glow brightly from the heat evolution that ensues during the reduction of the metallic oxide: on leading oxygen through the tube, when the reduction is over, and the mass has cooled down so as to be no longer visibly red hot, a still brighter glow is produced from the heat evolution during the reoxidation of the metal: the glowing is less bright in the first instance for the threefold reason that there is somewhat less heat evolved (31.2 units as against 37.6), whilst the resulting carbon dioxide escapes while very hot, and consequently removes heat; again it dilutes the carbon oxide and makes its action less energetic. (*Experiments performed.*)

In reference to the general rule just referred to relating to the connection between the heat evolution on combination and the relative action of bodies on one another, one particular case is noteworthy, of which reactions [A] and [B] afford a good example: if in a reaction of the form

$$x + y z = y + x z$$

there is little or no evolution of heat (*i. e.* if x and y both evolve approximately the same amount of heat in uniting with the same weight of z), it often happens that the converse reaction

$$y + x z = x y z$$

may be brought about by modifying the circumstances, so that the following is the general rule for all cases as regards the equation

$$x + y z = y + x z.$$

Case (1).—x evolves more heat in uniting with z than y does.

The reaction takes place under suitable conditions.

Case (2).—x and y evolve approximately the same amounts of heat in uniting with z.

The reaction may take place or its converse, according to circumstances.

Case (3).—x evolves considerably less heat than y in uniting with z.

The reaction (usually) does not take place, but the converse reaction frequently can occur under suitable conditions.

Thus in the case of reactions [A] and [B], there is but little heat evolution or absorption in either case.

[A]	Heat evolved by oxidation of carbon oxide to dioxide............	+ 68.8
	Heat absorbed by reduction of iron oxide..............................	— 66.7
	Heat evolved....................	+ 2.1

[B]	Heat evolved by oxidation of iron..	+ 66.7
	Heat absorbed by reduction of carbon dioxide to oxide...........	— 68.8
	Heat absorbed..................	— 2.1

In this respect reactions [A] and [B] may be compared with another well-known pair of inverse reactions, *viz.* the oxidation of iron by passing steam over it, hydrogen being evolved: and the reduction of iron oxide by passing hydrogen over it, steam being produced. In each of these cases, also, the thermal disturbance is not great, *i.e.* hydrogen and iron are thermally approximately equal in reference to their combination with oxygen at 500°.

STEAM AND IRON.

Heat evolved by oxidation of iron.....	+ 66.7
Heat absorbed by reduction of steam..	— 58.9
Heat evolved................ ..	+ 7.8

HYDROGEN AND IRON OXIDE.

Heat evolved by oxidation of hydrogen..	+ 58.9
Heat absorbed by reduction of iron oxide...............................	— 66.7
Heat absorbed....	— 7.8

From the existence of the inverse reactions [A] and [B] it results that when a mixture of the two oxides of carbon acts either on metallic iron or on iron oxide, oxidation of the one or reduction of the other takes place until a definite relation exists between the iron and oxygen present in the resulting substance and the two oxides of carbon in the gaseous mixture; the composition of the inert substance necessarily varies with the temperature and the nature of the mixture of carbon oxides used; the higher the temperature and the more carbon dioxide is present, the larger is the amount of oxygen present in the inert substance. Thus Bell obtained the following numbers:

CO_2 per 100 volumes of CO.	Temperature.	Oxygen in inert Oxide, $Fe_2O_3=100$	Carbon deposited per 100 of Fe.
600	Red heat..........................	90.0	nil
100	Bright red heat....................	67 5	"
47	Full red heat......................	8.2	"
11	Approaching whiteness	11.9	"
Nil (pure CO)	Bright red heat.................	1.0	0.3

Reactions [C]. The oxidation of carbon to carbon oxide evolves less heat than the conversion of iron into iron oxide; hence it might be inferred that iron will probably decompose carbon oxide with the evolution of heat, carbon being set free and an oxide of iron formed; thus thermally

Heat evolved by oxidation of iron.....	+ 66.7
Heat absorbed by reduction of carbon oxide to carbon..........................	— 27.4
Heat evolved....................	+ 39.3

The circumstances attending this change have been studied at great length by Bell; at temperatures not higher than 200° it is possible to obtain small quantities of deposited carbon in virtue of these reactions; but the action is at a maximum of about 420°–450°; at higher temperatures but little carbon can be obtained in this way, owing to the carbon-removing influences [D] and [E]; a few tenths per cent. of carbon, however, are always deposited, the same result being arrived at whether metallic iron or ferric oxide be employed in the instance. The oxygen communicated to the iron is for the most part removed again in virtue of reactions [A] and [D]; a minute quantity, however, is retained at all temperatures up to about 1000°. Since carbon is also present in the product, it might be supposed that the oxygen is present as occluded carbon oxide; that this is not the case, however, is shown by the circumstance that the whole of the carbon present is left behind in the free state on dissolving the impregnated iron in iodine water, or copper sulphate solution. Moreover, the oxygen present is, under these circumstances, left behind in the form of an oxide of iron.

The process acieration depends in the first instance on the occurrence of reactions [C]; carbon oxide is absorbed by the bars of iron, and is decomposed, particles of carbon being deposited and iron oxide formed, this latter being immediately reduced again, either by carbon oxide (reactions [A]), or by acting on a part of the deposited carbon (reactions [D]); the blisters on blister steel are probably produced by the attempts at egress of the carbon dioxide thus produced.

When ferric oxide is exposed to the action of carbon oxide at about 420°, the time required to produce a given amount of carbon deposition varies greatly with the physical structure of the iron oxide probably because this physical structure influences, as above described, the rate at which iron and lower oxides are formed in virtue of reactions [A]: thus the following Table indicates the relative amounts of carbon deposited from various kinds of ferric oxide, by similtaneous exposure to the action of carbon oxide at 420°, for seven hours:—

	Carbon deposited per 100 of iron.
Calcined ferric nitrate	144.0
Precipitated by ammonia	95.4
Calcined ferrous sulphate	54.5
Pumice-stone soaked in ferrous sulphate and calcined	14.9
Calcined Cleveland ironstone	0.3

After ten or twelve hours, however, the discrepancy is not so marked, as much carbon being then deposited with the Cleveland ore as it is with the precipitated oxide in seven hours.

The action of carbon oxide on certain other metals and their oxides has also been examined by Bell; the chief results arrived at are included in the following Table:—

Comparative Action at 400°–500° of Carbon Oxides on various Metals and Oxides.

Higher oxides of iron, nickel, and cobalt;
  Reduced to lower oxides, and partially to metal; suboxides (Fe_2O, Ni_2O, and Co_2O) being formed and much carbon deposited.

Spongy metallic iron, nickel, and cobalt;
  Partially oxidized, much free carbon being formed; iron most active, nickel least.

Higher oxides of manganese;
  Reduced only to monoxide (MnO); no free carbon being deposited.

Oxides of copper and lead;
  Reduced to metals; no free carbon deposited.

Oxides of zinc, chromium, and tin; metallic copper, lead, zinc, and tin.
  No effect.

In each one of these cases, where any action at all ensues, it is uniformly of such a nature as to be included in the general rule above laid down; thus nickel and cobalt give out approximately as much heat in uniting with 16 grammes of oxygen as does iron, and therefore behave in an analogous fashion, giving rise to converse reactions analogous to [A] and [B].

Reactions [D]. The occurrence of these reactions may be readily demonstrated by heating to redness an iron tube containing a mixture of carbon (as free as possible from hydrogen) and ferric oxide. As soon as the temperature rises to about 400°, carbon dioxide is evolved. The reaction, however, is complicated by the circumstance, that the evolved carbon dioxide reacts on both the carbon present and the iron or lower oxides of iron formed by reactions [D], so as to give rise to the production of carbon oxide by reactions [E] and [A] respectively; hence, as the action goes on, the amount of carbon dioxide in the mixture gradually lessens, and finally little but carbon oxide is evolved. (*Experiment performed.*)

It appears exceedingly probable that the so-called "occluded carbon oxide" contained in malleable iron is really not occluded at all, but is produced in virtue of these reactions from a mixture of carbide and oxide of iron; as already stated, on exposing pure metallic iron to the action of pure carbon oxide at a bright red heat, a substance is obtained containing both carbon and oxygen, *not* in the form of occluded carbon oxide. On heating this product, in a Sprengel vacuum, a mixture of carbon dioxide and carbon oxide is evolved (the latter predominating greatly).

The whole process of "puddling" depends on the occurrence of reactions [D]; the carbon present in the iron (together with other impurities) is thus eliminated by the reaction on it of iron oxides formed in the puddling furnace by the action of the heated air.

Reactions [D] are thermally abnormal; although carbon displaces iron from its oxide, the reaction is attended, not, as might be supposed, with an evolution of heat, but with a considerable absorption; thus at 500°.

Heat evolved by oxidation of carbon to carbon dioxide	+ 48.1
Heat absorbed by reduction of iron oxide	— 66.7
Heat absorbed	— 18.6

Reaction [E] is also abnormal, being attended with a still greater absorption of heat: thus at 500°,

Heat evolved by oxidation of carbon to carbon oxide	+ 27.4
Heat absorbed by reduction of carbon dioxide to carbon oxide	— 68.8
Heat absorbed	— 41.4

The physical structure of the carbon used has a considerable influence on the temperature at which both reactions [D] and [E] first take place; the lighter and more porous, the more readily is the carbon acted on; that deposited by reaction [C] is especially easily acted on; with ordinary charcoal or coke, reaction [E] does not appear to take place to any appreciable extent below 400°.

It is noteworthy that in some other cases besides reactions (D] and [E], where *solid* carbon is concerned, abnormal results are found to be produced; thus, by the action of carbon oxide on metallic zinc or tin, carbon should be set free even more readily than by iron, nickel, or cobalt, the oxidation-heat of each of the first two metals (per 16 grammes of oxygen) being greater than that of either of the latter three; in point of fact, however, no change at all ensues.

The gases of the blast furnace contain not merely carbon oxide and carbon dioxide, but also a large bulk of nitrogen; all experience, however, goes to prove that this acts solely as a diluent, and in no way interferes with the above-described reactions, saving in delaying them, *i. e.* causing more time to be required for their performance; the presence of nitrogen is, however, of great importance as regards another set of chemical reactions taking place in the lower portions of the furnace.

It has long been known that when nascent potassium or sodium vapor finds itself simultaneonsly in contact with carbon and nitrogen, the three elements combine, forming a metallic cyanide; the following experiment illustrates this fact: a small charcoal furnace is fed with charcoal previously soaked in potassium carbonate solution and dried; a strong blast of air is then injected into the lower part of the furnace, all apertures being well closed up with clay; when the temperature attains a high enough degree cyanide of potassium is formed,* and escapes to some extent along with other potassium compounds in the form of white fumes carried up by the escaping gases: by diverting these gases through a lateral tube into a vertical tower filled with flints, the solid fume is to a great extent deposited on the surface of the flints; by pouring water down the tower, the fume is dissolved and a solution of potassium cyanide (*inter alia*) trickles out at the base of the tower: on filtration and testing with ferrous and ferric salts and hydrochloric acid, this liquor gives an abundant prussian-blue reaction, showing the presence of much potassium cyanide. (*Experiment performed.*)

The cyanide thus formed acts on the last portions of unreduced oxide of iron, converting it into metal and becoming itself changed to cyanate; at the high temperature of the furnace near the tuyeres this cyanate is probably decomposed with the formation of an alkaline carbonate, and the elimination of nitrogen: a portion of the alkaline carbonate is again converted into cyanide; the majority, however, escapes, and is carried upwards by the stream of gases, and condenses as a kind of sublimate on the suface of the materials in the upper part of the furnace: considerable quantities of cyanides are also carried up in this way. The alkaline sorts thus condensed in the upper portions of the furnace are again brought down to the level of the

* The production of cyanide on the small scale in this way as a lecture illustration appears to be facilitated by the admixture of oxide of iron with the prepared charcoal, but is not always successful, the cause of failure being unknown.

tuyeres as the materials sink; hence each particle of alkali metal does duty over and over again, the alkalies introduced in small quantities in the fuel, &c., thus accumulating in the furnace to a very large extent. The enormous amounts of upwards of 4 cwt. of alkali metals and 2 cwt. of cyanogen per ton of iron made, have been repeatedly found in the gases near the level of the tuyeres. It appears very probable that the large excess of fuel required during the first few days of starting a new blast furnace is mainly due to the circumstance that cyanides have not formed to any great extent from the necessary want of this accumulation; after a very short time, however, considerable amounts of cyanides are found to be present in the gases.

These reactions afford an explanation of a circumstance which has for a long time been a difficulty in the minds of chemists who have studied the blast furnace. All observers agree that when the oxygen and carbon contained in the gases at various levels of the furnace are compared with the nitrogen, there is always more oxygen present than in ordinary air, and always more carbon than could be there were ordinary air burnt wholly to carbon oxide; thus the following Table illustrates the average composition by weight found by Bell in the case of an 80-foot furnace using calcined limestone:

Distance above Tuyere in feet.	0	6	12	25	37	50	60	76.5	Blast if wholly burnt. To CO.	Blast if wholly burnt. To CO_2.
Carbon dioxide....	1.2	trace	0.8	1.2	1.6	1.2	3.5	7.9	....	29.2
Carbon oxide............	37.6	37.1	35.9	34.9	34.8	34.8	33.2	33.0	34.4	....
Nitrogen................	61.2	62.9	63.3	63.9	63.6	64.0	63.3	59.1	65.6	70.8
CARBON and OXYGEN in the GASES at DIFFERENT LEVELS, calculated per 100 of NITROGEN.										
Carbon........	26.8	25.2	24.6	23.9	24.1	23.8	24.0	27.5	22.5	11.3
Oxygen..................	36.5	33.7	33.3	32.6	33.1	32.4	33.9	41.6	30.0	30.0

The presence of this excess of oxygen is readily accounted for when it is remembered that even at the lowest portions of the furnace some oxygen is still left in the ore, which is eliminated only at that point, necessarily in association with carbon, and that at this level the nitrogen of the blast is partially removed in the formation of cyanides. The anomaly, however, presents itself that the amount of oxygen appears to *diminish* from the tuyeres to a point some 10–12 feet above them, whereas it might be expected to increase, since the reduction of iron oxide is going on in the interval between the tuyeres and this point; inasmuch, however, as nitrogen is probably eliminated from the cyanide by its reaction on the residual oxide of iron throughout the whole of this interval, it results that *the nitrogen increases relatively to the carbon and oxygen in the gases;* or, what is the same thing, these diminish in reference to the nitrogen.

We are now in a position to trace out the general chemical changes undergone by the oxide of iron in passing through the furnace; for this purpose we may divide the furnace into three regions; in the uppermost tendencies [A] and [D] jointly are stronger than [B] and [C] jointly, and hence rapid reduction of ferric oxide takes place; in this region, too, tendency [C] is more powerful than [D] and [E] jointly, and hence carbon deposition takes place to a large extent. In this region, too, the limestone is for the most part calcined into quicklime, whilst if raw coal is the fuel employed, it is here coked; if carbonate of iron be used instead of oxide, it becomes converted into oxide in this region, the reducing and carbon-depositing reactions going on simultaneously with the formation of oxide.

In the middle region the iron-reducing tendencies are almost balanced by the iron-oxidizing ones, whilst the carbon-depositing tendencies are equalled and perhaps slightly excelled by the carbon-oxidizing tendencies: here reduction takes place, but only languidly, the chief effect produced in passing through this region being an increase of temperature.

In the lowest region, the reduction of the residual iron oxide is completed chiefly through the agency of the cyanides formed in the vicinity of tuyere; the reduced iron melts, dissolving a certain amount of the finely-divided carbon in contact with it, together with small quantities of sulphur, silicon, and phosphorous reduced by subsidiary reactions. The earthy constituents of the ore and the lime of the limestone also fuse, forming "slag" as above described. In the act of cooling, this solution of amphorous carbon in molten pig iron undergoes a remarkable change, whereby the carbon is converted to a greater or less extent into the allotropic modification graphite, which is insoluble in molten iron, and so separates in crystals, thereby giving a crystalline structure to the pig, and forming "gray" iron of a quality varying with the nature of the foreign ingredients which retard the allotropic transformation (*specimens exhibited*): thus in white iron and in spiegeleisen the transformation does not take place to any appreciable extent before solidfication. This allotropic change is precisely similar to that undergone by a solution of yellow phosphorous in carbon disulphide by exposure to light; in each case the more stable allotrope formed (graphite and red phosphorous) possesses less "intrinsic chemical energy," *i.e.* gives out less heat on combustion, so that the allotropic change is attended with an evolution of heat. The accompanying specimens of recently-prepared phosphorous solution (perfectly clear), and a portion of the same solution exposed to sunlight for some days (full of flakes of red phosphorous), illustrate this change. (*Specimens exhibited.*)

This action of light on phosphorous is in several respects analagous to the changes produced in various attenuated vapors by passing a powerful beam of light through them, as ably described and illustrated in this room by your Professor of Physics on a former occasion.

Had time permitted, I should have wished to refer to the practical consequences of these researches of Mr. Bell. In order to effect the smelting of iron a certain definite amount of heat is required to perform the general work of the furnace; the various items in this amount are indicated by the following Table:

APPROPRIATION of HEAT in an 80-FOOT FURNACE, during the PRODUCTION of 20 CWT. of PIG IRON from CLEVELAND ORE.

	Cwt. Heat-units.	
Constant requirements of furnace:		
Reduction of Fe from Fe_2O_3..	33,108	
Impregnation with carbon....	1,440	
Reduction of P, S, and Si....	4,174	
Fusion of pig iron....... ...	6,600	
Radiation from walls of furnace......................	3,658	
Cooling tuyures by water......	1,818	
Conduction to earth and other sources of loss not determined................ ...	3,202	
		54,000
Variable sources of loss of heat:		
Fusion of slag................	16,720	
Expulsion of CO_2 from limestone.......	5,054	
Decomposition of ditto.......	5,248	
Decomposition of H_2 O in blast...............	2,720	
Evaporation of H_2O in coke..	313	
		30,055
Carried out by escaping gases.......		8,860
Total..		92,915
Brought in by hot blast.............		11,919
Heat produced by combustion of coke................................		80,996

To produce this heat with a minimum expenditure of fuel, it is necessary that the whole of the carbon used as fuel should be oxidized in the furnace to carbon dioxide; the relative strengths of the forces involved in the 9 reactions above described are, however, such that it is not possible to convert more than about 35 or 40 per cent. of the carbon burnt into carbon dioxide, the rest necessarily escaping as carbon oxide. Hence much less heat is generated in the furnace than would be if the fuel could be wholly burnt to carbon dioxide; that is, more fuel must be used to do the work of the furnace. It hence results that if the exigencies of commerce or of nature should require that metallic iron should be obtained from its ores with the consumption of a materially less amount of fuel than is now necessary for the working of a blast furnace of the best description, some wholly dissimilar form of apparatus will be requisite for the purpose. [C. R. A.W.]

PUMPING-ENGINES.—At the last meeting of the North Staffordshire Institute of Mining Engineers, Mr. Woodworth, of Longton, read apaper on recent improvements in pumping-engines for mines.

In the course of his reading he remarked that in designing steam machinery of all kinds, the great questions to be borne in mind were economy of fuel, of maintenance, and of construction. The importance of economy of fuel was manifest when they considered that the steam-engines in this country alone consumed nearly forty million tons of fuel per annum, so that a small percentage of saving, by whatever means obtained, represented a considerable addition to the national wealth. While the cost of coal in Cornwall had been a subject of vital importance ever since the steam-engine was introduced, it was not to be wondered at that the earliest steps were taken to secure as great an advantage as possible by the economical use of steam in draining the mines, although they found that the duty of the engines in that district had receded considerably for the last twenty years or so, as the rage for extreme limits of expansive working had been carried so far that the cost of maintenance and risk of accidents were so great as to more than counterbalance the benefits derived from an extreme range of expansive working. The Cornish engine in itself was a very costly machine in the first case, being only a simple-acting engine, and lifting a constant load compelled it to have a great weight of matter to put in motion quickly during the first portion of the stroke if worked expansively, so that sufficient energy could be stored up to enable it to complete its stroke after the steam was cut off at the point desired, and then the water was lifted steadily on the outward stroke by the action of gravity alone; while the differential pumping engine could be fixed either at the bottom of the pit, dispensing with the cumbrous rods entirely, or on the surface, as desired, and working double acting, was nothing like so costly, either in engines or buildings, for the same power, and such was the absolute safety of the action of the valve gear, that the load might be entirely thrown off when the engine was in full work, with the stop valve wide open with impunity. For the draining of dip workings the late Messrs. Garrett, Marshall, and Co. designed the direct-acting hydraulic engine and pump to be worked from the main column of pumps, or anywhere where sufficient water-pressure was available, and there was a wide field for its application in all districts where there was a head-pressure of water, which was often to be had at a nominal cost. The differential engine had been in operation for some years, and had been fixed in a number of collieries, the highest lift at present being at Clay Cross, where they were working against 1000 feet head of water; and some very large ones were being made for Germany, to pump against 900 feet head of water, with hydraulic engines to pump for a short distance below, to avoid all risk of the engines being flooded through any cause, as the hydraulic engines would continue working equally as well under water as above. Attention was called to the engine designed by Mr. H. Davey, of Leeds, and for which many advantages were claimed.

HYDRO-THERMIC MOTIVE POWER, &c. —A series of inventions, closely connected with each other, have been patented by Mr. F. TOMMASI, of Paris, embracing three applications of hydro-thermic motive power, the first being an improved motive power engine. This machine is composed of two or more cylinders, filled with oil or other liquid; it is set in motion by the alternate expansion and condensation of this liquid. To produce the expansion hot water or steam is made to circulate through small tubes plunging into the liquid, and to produce the condensation cold water or any other refrigerating mixture is made to pass through the same small tubes. The liquid expanding and condensing alternately drives the pistons in and out of their cylinders, thus producing a come and go motion, which may be transformed into a circular motion by ordinary means. If, as is preferable, hot water is used, the actual working of the machine returns to the boiler the hot water which has circulated through the small tubes, thereby giving a great saving. The distribution of the steam or hot water and of the cold water is effected by means of ordinary side valves, set in motion by a cam, in lieu of an eccentric, in order to render the distribution almost instantaneous.

The improved hydro-thermic riveting machine, based upon the same principle, is set in motion by the alternate expansion and condensation of oil or any other liquid contained therein. To produce the expansion hot water or steam is made to circulate in small tubes plunging into the oil or other liquid; and to produce the condensation cold water or any other refrigerating mixture is made to circulate through the same small tubes. When the liquid is under expansion it lifts a vertical piston, which raises counterweights. The hot rivet is then placed between puncheons, one of which is stationary, and the other fixed to a horizontal piston, which, like the first-mentioned piston, also plunges into the liquid; this horizontal piston is clutched by a cam lever, but at this moment it is released (and driven by the pressure of the other piston, which is rapidly brought down by its counterweights), suddenly advances, and rivets the rivet. The cold current is then substituted for the warm one, the horizontal piston is brought back, to its place, and the operation recommenced.

The third patent relates to an improved hydro-thermic punching machine, which is set in motion by the alternate expansion and condensation of oil or other liquid contained in the machine. To produce the expansion hot water or steam is made to circulate within small tubes plunging into the oil or other liquid; and to produce the condensation cold water or other refrigerating mixture is made to circulate through the same small tubes. When the liquid is under expansion it drives down a piston furnished with a punch; and thus punches the plate of metal submitted to its action. The descent of the piston also effects automically (by means of a particular arrangement of side valves or cocks) the substitution of the cold circulation for the hot one, which brings the piston back to its place. The return of the piston to its place substitutes the hot circulation for the cold one, the work recommences, and so on.

Emery.—The crude emery stone, which is a variety of corundum, has never been found in any considerable quantity for consumption, except in the countries bordering on the eastern part of the Mediterranean Sea, near Smyrna, on the Asiatic Continent, and on the contiguous island of Naxos, from which two sources all the world is supplied. Emery is very abundant in the island of Naxos, at Cape Emeri, which is the property of the Greek Government. Dr. Lawrence Smith, the American geologist, while residing in Smyrna, made a discovery of a deposit of emery. He made an examination of the locality in 1847, and having reported his discoveries to the Turkish Government, a commission of inquiry was instituted, and the business soon assumed a mercantile form. All that is used at present in the arts comes from Turkey, near ancient Smyrna, and from Naxos, which sources seem to be the same geological deposit reaching under the sea, from the Continent to the island, in the same manner as the basaltic formation of the Scotch Fingal's Cave and the Irish Giant's Causeway stretches under the Irish Channel. A few years since there was found in Hampden County, Mass., U.S.A., a species of hard iron ore, and, during the late civil war in America, large quantities of it were mined and crushed, and sold in the United States as real emery; but chemical analysis and experience in its use have shown consumers its different nature. The contractors who work the Turkish and Greek mines are obliged to mine, at each, from 2000 to 2500 tons per annum. The maximum annual product, and the total consumption of crude emery for all uses, does not exceed 5000 tons, and often falls below that quantity, of which the Wellington Mills, London, consume one-fourth of all that is yearly mined. The mining of the emery is of the simplest character; the natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an earth, in which the emery is found embedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. Its color varies from red-brown to dark brown. Its specific gravity is about 4.4, and it is so hard as to scratch quartz and many precious stones. The earth in the neighborhood of the block is almost always of a red color, similar to red oxide of iron, and serves as an indication of its proximity to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod, with a steel point, and when any resistance is met with, the rod is rubbed in contact with the resisting body, and the effect produced on the point enables a practiced eye to decide whether it has been done by emery or not. The blocks, which are of a convenient size, are transported in their natural state, but are frequently broken by large hammers. When they resist the action of the hammers, they are subjected to the action of fire for several hours, and on cooling they commonly yield to blows. The crude stone is shipped in blocks of various sizes, from 150 lb. in weight, down to pieces the size of an egg, but large stone is preferred, being more compact and hard. It sometimes happens that large masses are abandoned, owing to the impossibility of breaking them into fragments of a size convenient for transportation to the sea coast, camels and horses being the only means of transportation.—*Emery Grinder.*

REPORTS OF ENGINEERING SOCIETIES.

The American Association.—Last summer, at the Hartford Meeting of the American Association for the Advancement of Science, a new constitution was adopted, and under its provisions a permanent sub-section of "Chemistry, chemical physics, chemical technology, mineralogy, and metallurgy," was organized. Professor S. W. Johnson, of Yale College, was elected Chairman of the new sub-section for the ensuing year, and Mr. F. W. Clarke was deputed to make the necessary efforts to insure a full attendance of chemists and others interested in the application of chemistry. The meeting for this summer will be held at Detroit, commencing the 11th of August, and continuing about a week. It is very desirable that there should be a full attendance in the new sub-section in order to make it a success. Any one who is interested in chemistry, mineralogy, or any application of these sciences will be welcome.

Hitherto chemistry has been but little represented in the proceedings of the Association, and the time now seems to have arrived in which some good work can be done.

IRON AND STEEL NOTES.

Bessemer and Siemens-Martin Steel.—A foreign cotemporary thus discusses the relative merits of the Bessemer and the Siemens-Martin process: There are at least two defects in the application of the Bessemer process, or perhaps it would be better to say, two obstacles to be encountered in the practical working of the method, that seem very difficult to overcome. One is the almost impossibility of using directly pig irons containing sulphur and phosphorus in any appreciable quantities, and the other the difficulty of controlling the quality of the product. These obstacles are too well known to need enlargement. Though the first is not so serious in America as in England, owing to the large deposits of ore in various localities suitable for the manufacture of Bessemer pig, nevertheless the cost of making pig suitable for this process is so much greater than the cost of ordinary pig as to be a large item in a ton of rails. The difficulty in controlling the amount of carbon is also well known, and is a serious item in the expense. In every cast made the carbon must be determined, sometimes by chemical analysis, and again by tests of a mechanical nature.

The Siemens-Martin method has the advantage of the Bessemer in these particulars—irons containing a much higher percentage of both phosphorus and sulphur can be used, it being estimated that about two-thirds of the sulphur and three-fourths of the phosphorus are eliminated in the process. The crop ends of bars, scraps, all descriptions of waste and old wrought iron, can also be utilized; in a word, grades of pig iron that could not be used in the Bessemer process, and much that would be waste, can be readily used. In the Siemens-Martin process the quality of the product is completely under control. Should the metal at the time of testing be too soft, more pig can be added; while, if it is too hard, simply waiting a few minutes will correct this, and materially soften the metal. The loss in the open hearth process is considerable less than in the converter—according to Gruner, about one-half.

The great advantage of the Bessemer process is in the larger amount of steel produced per day, and the cheaper cost of production. In some instances the amount has, with a pair of five-ton converters, exceeded 200 tons; while 10 tons would be a good day's work with an ordinary open hearth furnace. With the Pernot modification of the Siemens-Martin furnace, there is a prospect that this objection may be overcome. It is claimed that, with Pernot's furnace, 40 tons per day of Siemens-Martin steel can be produced, and we have the authority of an eye-witness for sayiug that the claim is well-founded. If this is true, with six of these furnaces a product fully equal to that of a pair of five-ton Bessemer converters could be obtained. The cost of the plant would not be more than half that of a Bessemer, the quality of the product could be controlled with ease, pig iron inferior to that used in Bessemer could be utilized, all scraps could be worked over, and the cost of steel equal in grade to Bessemer would not exceed the latter.—*Bulletin.*

RAILWAY NOTES.

A SIBERIAN RAILWAY.—Some hundreds of the principal merchants of Russia have forwarded an address to the Russian Minister of Public Works, asking that the construction of a railway to Siberia *via* Nijni-Novgorod may be accelerated. Surveys for the proposed line were made so long since as 1867 and 1868, but since those years scarcely anything has been done in the matter.

UNDERGROUND RAILWAY AT CONSTANTINOPLE.—A telegram from Constantinople announces the opening of the Pera and Galata Underground Railway. The length of this line measured between the facades of the two termini is 635 metres. The station of Galata is situated between the Koumrou and Sevoud Streets; and that of Pera, which is not yet completed, in the Rue Nadir. The tunnel is ventilated by two shafts, one of which is 24 98 metres in depth, and the other 20.23. This railway is worked by a fixed engine, the carriages being hauled by a rope at the rate of 18 kilometres—11¼ miles—per hour; the trains are run at intervals of five minutes. The difference of level between the two stations is 60 metres, so that the average gradient is about 1 in 10. It is estimated that the number of passengers carried daily will be 30,000. The cost of construction of this line was upwards of 5 millions of francs—£200,000.

IMPROVEMENTS IN ROLLING STOCK.—The artizans of the German Railway administration, in their sixth annual, report that locomotive boilers made of sheets of cast steel have not fulfilled the expectation entertained for them, although it is hoped that more favorable results will be obtained when improvements have been made in the manufacture of the steel plates. Copper bolts are recommended for the first row; steel ones are only to be employed when the feed-water and fuel are both good. Locomotive boilers have been made to resist a pressure of ten atmospheres. Screw link motion answers well for locomotives where the slide motion is not too heavy. In general the lever is to be preferred. Cast iron slide valves are good, and last longer, if the material possess the right hardness; brass ones are expensive and soon wear out; iron bronze gives satisfactory results; slide valves with partial lining do well, but cannot be employed if grooved. A number of companies have had bad luck with lined valves. For locomotive and tender axle boxes a majority of the railway companies recommend brass with white metal lining. Some had favorable results from the use of white metal alone; very few employ the red without lining it with an alloy, usually 87 parts copper and 13 tin, or 23 parts copper and 5 tin, also 82 copper and 18 tin. No definite results have been obtained from the use of phosphor bronze. The Heberlein brake has been generally successful; yet in many respects it may be improved. Iron blocks or shoes are gradually replacing wooden ones for brakes; wrought iron shoes have not been sufficiently tested, cast iron ones wear out quite rapidly, which makes them expensive. Those of cast steel or cast iron mixed with steel filings are recommended.

PUNCHING RAILS IN PLACE BY STEAM.—A new machine for punching has been introduced into the railway world of America called Dudgeon's Hydraulic Punch, to which steam has recently been applied by Mr. N. Tilton, for punching rails in place, and as the application seems to have been successful, we reprint the report of this gentleman on the same:

The thickness of rail where punched is ⅝ and ¾ inches, is the old pattern of chair or Erie rail, and is of such shape that at the top and bottom of the hole the thickness is ¾ of an inch, while at the centre it is but ⅝, and is therefore much more difficult to punch than if rolled with two very nearly parallel faces. The portion of our iron which has been repaired at the ends is in most cases thicker by ⅛, and sometimes ¼ inch; this, of course, makes it still more difficult to punch.

The size of the holes is 13-16 by 1 inch. When working one punch by hand we have only been able to punch from fifty to eighty holes in one day. By steam we have punched from 100 to 200 per day. The reason that more are punched in one day than another is, that we at times work one or two days without breaking a punch or die, and at other times have broken as many as four punches and one die in a single day. The causes of the breakage of so many are the irregular shapes of iron, the difficulty of getting the top and bottom of the punch to strike at the same time; if too high it crowds down, and if too low it crowds up. I mean by irregular-shaped iron that which has been repaired. It only requires ordinary care to be able to punch the holes accurately. No trouble has been experienced in making the plates fit properly. It is desirable that both punches be worked side by side, but impracticable, as one or the other is almost daily breaking punches, or having to stop to renew the leather packing in the ram or screw of the punch.

To work one punch by hand, it requires eight men; two to go ahead and draw the spikes, remove the chairs, and block up the rail one inch high; three men are required to work the punch, one to put on the plates and bolts, and two to tamp up the ties after the punch. I think the maker of these punches claims that two men are all that are necessary to work the punch, but we have found it necessary to use three. To work one of our steam punches, it requires twice the number of work. To work the punch but two are required. The cost of the fuel, &c., to run the steam punch does not exceed one dollar per day.

The breaking of the dies and punches, and the repacking of the rams and screws is about equal to that while working by hand, in proportion to the work done. I think we should break but few punches and dies, nor should we destroy the packing of rams and screws often, if we had iron to punch of the ordinary "fish" pattern, where the two sides are so nearly parallel, for the reason that there would be no tendency to crowd the punch down or up. It is often the case, with our "Erie" iron, that the die goes down and the punch goes up, thereby forcing them "out of line," resulting in breaking one or the other—sometimes both—or the packing is destroyed in the screw or the ram.

I am satisfied that the steam punches are doing the work much more economically than it could be done by hand, and twice as fast. The cost of each will, of course, have to be considered, together with the quantity of work to be done. It has cost us about 600 dols. to apply steam to each punch.—*Iron.*

ENGINEERING STRUCTURES.

An Aerial Bridge.—A great engineering work, the only one of the kind in France, is about to be executed at Lyons. It is an iron bridge to connect the plateau of Fourviers with that of the Croix-Rousse, which are two heights, like that of Montmartre in Paris, at a distance of 300 metres from each other. *Galignani* says: This undertaking is estimated to cost 2,800,000f., of which a subvention of 600,000f. only is asked from the city. This aerial bridge will consist of three spans, the central one of 135 metres, and two others of 70 metres each, resting on open iron columns in a line with the houses on the quays. The platform of the bridge will be 65 metres above the road, and nearly 50 metres above the houses. Each of the two central columns will have inside a lift by which pedestrians will be raised in two minutes at a charge of ten centimes, to the top, whence they may reach the higher parts of the city, where they may have business.

An Important Engineering Work in Portugal.—From St. Michaels an official report has been issued with regard to the progress of the works for the construction of the artificial harbor of Ponta Delgada. It is mentioned that the breakwater forming this artificial harbor has attained an extent of 580 metres, the projected length being 860 metres at low-water mark. In 1873 no progress was made as regards length, the whole of the stone thrown into the sea—amounting to 67,290 English tons—having been employed in completing the section at the far end, as a considerable portion had been washed away during the gales of the previous winter. The expenditure during the year was £19,325, making a total of £317,722 since the commencement of the works. With regard to the extent of the works, it is calculated that as much as 2,341,104 tons of stone will be required to complete the breakwater, and that of this amount nearly 2,000,000 tons have already been employed. The portion so far constructed, we learn, does not yet present the form definitely adopted—that of the breakwater at Holyhead but has an appearance of solidity which is a guarantee of its resistance against the violence of the sea. To effect the completion of the work it is believed that ten years will be required, and that the annual grant of about £18,000 will not be exceeded. The part of the artificial harbor already sheltered has an area of about 25,000 square metres, with a depth varying from 10 ft. to 30 ft. below low-water mark. Vessels drawing 20 ft. can enter this part of the harbor. The part of the artificial harbor corresponding to the portion of the breakwater still to be completed will present an area of more than 90,000 square metres, with a depth varying from 10 ft. to 60 ft., and admitting about 100 vessels of all sizes. The construction of a new quay has also been commenced, alongside which vessels drawing 18 ft. will be able to discharge. It is stated that the length of the quay will be 50 metres. The engineer who has the direction of the works of the artificial harbor of Ponta Delgada is Senor Alvaro Kopke de Barbosa Ayalla.—*Engineering.*

Effects of Heat and Cold on the St. Louis Bridge.—We have here in St. Louis a bridge with arches of 500 feet; and, to any one who has the proper means of observation, the changes in the elevation of the crown of the arches are very perceptible. In the construction of the work, calculations and allowances were made for the extremes of temperature, through a range of 140°, from the greatest cold in winter to the warmest day of summer, and the calculated difference in the elevation of the center arch of the upper chord above the City Directrix at these two times was about eighteen inches.

The bridge has now long been finished. During the year, the height of the center piers of the top chords of the arches above the City Directrix has been noted almost daily at temperatures which have ranged from 92° to 15° Fah., the elevations being taken with a level from the abutments of the bridge.

(The "height" is that of the center pier of the top chord above the City Directrix):

Date.	Temp. 3 P. M.	Height in feet.
May 6th, 1874	69° F.	63,548
June 29th, 1874	77° F.	63,688
July 20th, 1874	91° F.	63,757
January 4th, 1875	10° F.	63,241
January 9th, 1875	15° F.	63,065

Between the figures for July 20th last and those for January 9th, which two days are respectively the warmest and coldest of the year, there is a difference in temperature of 107° Fahrenheit, and of 0.692 feet, or nearly 8 5-16 inches.

This is an effect of temperature much less than calculated, due partly to the fact of the iron work being painted white, which lessens the absorption of heat in hot weather, and increases the radiation in cold weather, and also the protection afforded by the roof of the bridge. This latter is strikingly exemplified in the fact that the river, while frozen above and below the bridge, has yet been open under it.—*Railway World.*

Iron Bridge Cylinders.—The following hints on this subject are taken from Mr. John Newman's useful pamphlet on "Iron Cylinder Bridge Piers," recently reviewed in these columns: As the strength of cast iron depends upon its rigidity, it is necessary to stiffen the cylinder rings by lugs or brackets, and vertical and horizontal flanges, which also form the joint flanges. The joints should be made slightly stronger than the solid parts of the work, as they are subject to special defects, such as unequal bearing, &c. The vertical and horizontal flanges of the cylinder should be well and firmly bolted together, as the lateral strength of the cylinder is thereby secured. It may be as well in cylinders of small diameter to lessen the length of each ring and make them in one piece, thus obviating the necessity of any *vertical* joint flanges, and with the increased facilities and improved machinery now in use, many ironmasters will do this without any extra charge. In tropical climates, where the atmosphere affects the metal to a greater extent than in Europe, ample allowance in the thickness of the cylinder should be made. There is greater liability to imperfections in the castings if the rings forming the cylinder are cast horizontally instead of vertically. In increasing the thickness of the rings of the cylinder, the same unit of strength per square inch for the increased area does not hold, for beyond a certain thickness the value per square inch decreases very considerably. The author would never use a less thickness of cast iron in the rings of the cylinder than 1 inch, or a greater thickness than 2½ inches, and this latter only as an exceptional case; and for the bottom ring, which, to facilitate the sinking, is generally brought to a taper. Castings are generally made of greater thickness in practice than the requirements of theory show as necessary. Cast iron is more liable to be broken by collision with floating substances than wrought iron. It is usual when a bolt passes through a piece of cast iron to increase the thickness of the metal at that point to a little beyond where the head or the nut of the bolt extends. A bad joint will often not be discovered on testing a structure, but only after it has been subject to continuous strain and vibration; thus the importance of good and sound joints is evident. It is advisable to make the bottom ring of the cylinder thicker than the other rings, on account of the greater cross strain, &c., it has to bear. Much of the strength of a casting depends on the design. There should be as few abrupt bends, sharp angles, and sudden variations of thickness as possible, in order to obtain equal and uniform cooling, and accord in the order and direction of crystallization, as it has been found from experience that wherever the order of crystalization is disturbed there will be found weakness. Increased thickness should not be considered as an equivalent to inferior iron, for in no material can it be said with greater truth that it is absolutely necessary to have quality as well as quantity.—*Iron.*

THE LONDON WATER SUPPLY.—In reply to Lord Cadogan, who in the House of Lords the other evening asked what the Government intended with regard to the better and purer supply of water to the metropolis, the Duke of Richmond referred to a Bill which the Chelsea Company had now before Parliament for enabling them to draw from a source higher up the Thames than they have at present. The Chelsea Company was specially complained of by Lord Cadogan, and a friendly journal which includes in its title the advocacy of sanitary improvement, admits that this company is "unhappily every now and then obliged to distribute water somewhat turbid, which, when it gets into a cistern, deposits something like mud." Turbid water, when allowed to settle, does, it must be admitted, usually deposit something that cannot be easily discriminated from mud. From Major Bolton's report for January to the Local Government Board, we learn the composition of this sediment, resembling mud, which the company referred to dispenses to its customers. The greater part of it consists of the chalk and clay carried down by floods, and to this must be added the solid matters of the "filthy outflow of the rivers Mole and Rye," below which the intake of the company is situated. No wonder, then, that a deposit "thick and slab" should appear in the cistern. Major Bolton's general report is pretty favorable, and he shows that great difficulty has been experienced by the companies in their filtering operations during the prevalence of the recent extraordinary heavy floods, which tended to choke the filters by a deposit of chalk, mud, and clay upon the surface of the sand, thereby rendering the utmost vigilance and exertion on the part of the companies necessary to enable them to properly filter their supply. With the praiseworthy intention of allaying the public alarm and anxiety, he draws attention to the following extracts from the report of the royal commission on the quality of the water from the Thames basin:—"The evidence before us leads to the conclusion that the Thames water has many good qualities which render it peculiarly suitable for the supply of the metropolis, and which give it in some respects a superiority over the soft waters usually obtained from high gathering grounds. When properly filtered, it is clear, bright, colorless, agreeable, and palatable, and the amount and nature of its saline constituents are considered by many to contribute to its general acceptability for drinking. It is well aerated, has good keeping qualities, and is unusually safe as regards action on lead and iron. The evidence we have collected on the subject of the organic impurities of this water presents great diversities of opinion, but there is one result which we think is clearly deducible from the facts before us, namely, that in the present state of chemical science (1869) analysis fails to discover in properly filtered Thames water anything positively deleterious to health. Whatever may be the difference of opinion with respect to the time required for removal of all the objectionable organic matter, all the chemists agree that in Thames water taken from the present source and properly filtered, all such matter has disappeared, and that the resulting compounds, such as nitrates, &c., remaining therein, are innocuous and harmless."

ORDNANCE AND NAVAL.

German Artillery.—It is stated by Prussian artillerists that, notwithstanding certain adverse comments made on their new heavy field pieces in the reports of the Vienna International Exhibition, it has been privately resolved by the Austrian War Office that the whole of its artillery shall be converted as speedily as possible to a model borrowed directly from the Prussian.

A Brazilian Arsenal.—The length of the workshop quays at the Brazilian arsenal, at Ponta d'Ares, is 300 metres; and the breadth of the quays is from five metres to six metres. The great boiler shop has 14 machines for pressing, punching, cutting and bending bars and plates of iron; all these machines are driven by a portable steam engine of 25 horse power. The arsenal turned out last year several bridges of wide span for railways, and a number of boilers, both tubular and common. The machine shop has 48 machine tools of various types.

BOOK NOTICES

Diagrammagraphic. By S. Pichault. Price, $2.40. Paris: J. Dejey & Co. For sale by D. Van Nostrand.

This is a treatise on theoretical and practical use of an "Indicator," whose construction is fully described by text and plates.

Les Croiseurs; La Guerre de Course. Par P. Dislere. Paris: Gauthier—Villars. Price, $2.40. For sale by D. Van Nostrand.

This is a sketchy account of modern ships of war, particularly of the English, French and American navies. There are a few cuts and many statistical tables.

Fosses D'Aisances. Paris: J. Baudry. $8.00. For sale by D. Van Nostrand.

This is an elaborate treatise on the theory and use of the water-closet and its congeners.

The work ought to be of great value to the practical plumber, the sanitary inspector, and the hospital surgeon.

We had no idea of the extent of the subject until we turned over the pages of this work. There are 550 pages of text, and 232 excellent wood-cuts.

Annual Report of the State Engineer and Surveyor of the State of New York on the Railroads of the State. Albany: Weed, Parsons & Co. Price, $2.00. For sale by D. Van Nostrand.

This bulky volume of 1,037 pages presents in tabulated form all the statistics usually included in such reports; it includes also the "General Railroad Act," the laws amending the same, and other general laws relating to the railroads of the State.

Narrow Gauge Railways in America. By Howard Flemming. Price, 50 cts. For sale by D. Van Nostrand.

This is a compilation of statistics which have been much demanded for the last two or three years.

In addition to the engineering facts relating to the narrow railways, a complete directory of all such roads in this country is appended.

Wooden and Brick Buildings with Details. A. J. Bicknell. New York. 2 vols. Price, $18.00. For sale by D. Van Nostrand.

This is a collection of designs by many American architects.

The plates are large quarto size, and number 160.

The small amount of text is probably sufficient where detailed plans are so fully given.

Such examples by successful architects are invaluable to young aspirants to architectural fame.

Astronomy. By J. Rambosson. London: Chapman & Hall. Price $6.00 For sale by D. Van Nostrand.

This is a popular treatise presenting some acceptable differences from the average popular texts-books.

Historical sketches of early astronomers and their labors; the history of the earth's measurement; accounts of the great comets and descriptions of meteors and meteorites are rendered in a pleasant and readable form. The illustrations are highly colored but poor.

Wood and Its Uses. By P. B. Eassie. New York: D. Van Nostrand. Price $1.50.

The text of this neat little treatise treats of the following subjects in order: Timber and Deals—Joists, Flooring and Girders—Roofs and Roofing Materials—Joiner's Work—Contractor's Plant—Green-Houses and Vineries—Useful Temporary Structures—Strains on Roofs and Bridges—Practical Memoranda and Tables.

Cuts to the number of 230 illustrate the text. That the work is eminently practical may be correctly inferred from the list of topics.

Continuous Revolving Drawbridges. By Clemens Hersehel. Boston: Little, Brown & Co. Price $1.50. For sale by D. Van Nostrand.

This was originally prepared for the American Society of Civil Engineers, and is in their published transactions. It is now put in an exceedingly neat form, and is entitled to place among standard works of engineering literature.

It will prove a valuable aid to students; the method of computation is arithmetical, and is extended to the important case of continuous girders.

Elements of Descriptive Geometry. In Three Parts. Part I—Surfaces of Revolution; Part II—Surfaces of Transposition; Part III—Special Subjects. By Prof. S. Edward Warren. New York: John Wiley & Son.

Nothing could be more thorough than the method of treatment of Prof. Warren in any department of Graphics. He is doubtless the most experienced instructor of these subjects in this country, and judging by the fruits of his labor among the young members of the engineering profession he has been the most widely successful. He is the author of several works, but the one by which his skill as an instructor may be most accurately estimated is the complete work on Descriptive Geometry, divided into separate volumes as indicated above. The first part includes all of the ordinary college course in this department of science, while the remaining portions are designed to satisfy the wants of the most advanced technical schools. The former large work in one volume is out of print; and in re-writing the work a new arrangment of subjects was decided upon; this resulted in the above division.

RAPID TRANSIT AND TERMINAL FREIGHT FACILITIES. By a Committee of the American Society of Civil Engineers. Published by the Society. Price 75 cts. For sale by D. Van Nostrand.

A Committee of five members of the Society was appointed in September last "to investigate the necessary conditions of success, and to recommend plans for—1st, the best means of rapid transit for passengers; and 2d, the best and cheapest methods of delivering, storing and distributing goods and freight in and about the City of New York.

The two reports were rendered on March 3d and March 17th respectively, and are published together.

Considering the circumstances under which this report was framed, the professional standing of the several members of the Committee, and the influences which urged them to a careful consideration of the subject, we can safely say, that from no other source could such a document issue with so strong claims to our respectful attention.

ELEMENTS OF MACHINE CONSTRUCTION AND DRAWING. Elementary Plane Problems; Elementary Science Perspective; Linear Perspective. Prof. S. EDWARD WARREN. New York: John Wiley & Son.

The first of the above list is a good work for the young draughtsman, after he has mastered Geometry and Geometrical Problems. It presents in logical form the Principles of Gearing; of Screw Propellers, Valve Motions, Governors, &c., &c.

The plates are numerous and well designed.

For beginners in Graphics, the second of the above list is specially designed. It deals with the problems on the point, straight line and the circle, and furnishes excellent suggestions to teachers of Elementary Geometry in the way of applications during the student's early progress.

Elementary Linear Perspective is rudimentary. It is a small work of only 116 pages, and is illustrated with 66 cuts. It contains as much perspective as landscape artists attempt to acquire.

Linear Perspective presents the subject fully. It is a volume of 200 pages of text and 17 folding plates.

The following index of chapters will exhibit the scope of this excellent treatise:

General Principles—General Tables—Fundamental Problems—Perspectives of Forms only—Special Principles and Operations—Elementary Perspectives of Shadows—Problems of Forms and their Shadows—Perspectives of Reflections—Perspectives of Shadows by Candle Light—Distorted Perspections; Singular and Amorphous.

KNIGHT'S AMERICAN MECHANICAL DICTIONARY. A Descriptive Word-Book of Tools, Instruments, Machines, Chemical and Mehanical Processes and Engineering Works. By EDWARD H. KNIGHT, Civil and Mechanical Engineer. New York: J. B. Ford & Co.

This is an entirely new work, both in conception and construction, being at once a Cyclopedia of information on generic subjects, and, more especially, a Word-Book or Dictionary, with descriptive definitions of machines, tools, instruments, processes, &c., in their alphabetical order, forming a really complete reference-book of information concerning the mechanical appliances of science and the industrial and fine arts.

Mr. Knight, the author of this work, besides being a practical Civil and Mechanical Engineer of high attainments, has for many years been in that best mechanical school of the world, the U. S. Patent Office, where the most inventive and ingenious people of the earth bring in their new ideas. For years he has been employed to classify and systematize for examination the 20,000 inventions per annum which come pouring into that vast depot; and as the Editor of the Patent Office Reports to Congress, he has acquired a singular aptness, clearness, and terseness in describing the application of mechanical principles.

The technical illustrations, nearly 6,000 in number, are never introduced for mere ornament, but always to exemplify the text; and, besides being profuse in quantity, are clear, intelligible, and artistic.

THE IMPROVEMENT OF NAVIGATION OF THE ST. LAWRENCE RIVER.

The Chief Engineer's (of the Dominion of Canada) report on the St. Lawrence navigation improvements, including the canal enlargement, is out. There is not much in it that is new. The present canals are found to be too small to accommodate the growing trade of the west; they were designed with locks 200′×45′ and 9′ water on the mitre sill, although there has been times when there was only 7′. The proposed canals are to have locks 270′×45′ and 12′ water on the mitre sill at low water, and also have the other dimensions in proportion.

It is also proposed to have a chain-tug service in the rapids. This is not anything new, as it has been employed on the Seine below Paris, also on the Rhine, Elbe, Danube, and other rivers and canals in Europe, as well as at Hochilaga, below Montreal.

The chain is made fast to a pier above the rapid and to another below, and the tug works backwards and forwards on this chain.

There are some works in connection with those improvements that will be very difficult in execution, such as sinking piers in the rapids, &c.

It may be noted here, that a vessel that can run 12 miles an hour cannot ascend a rapid running 7 or 8; and a man can tow a canoe in a rapid that 6 men could not paddle against the same current.

If some person could give some reliable information about this chain-tug towing, and also about the resistance of water to passing vessels, especially in strong currents, they would confer a benefit on the profession, as I think this is but little understood.

Those St. Lawrence navigation improvements are estimated to cost about $12,000,000, but if the chain-tug towing is adopted in the rapids it will reduce the cost to about $10,000,000. It is intended to complete the works by May, 1879. FRANK C. TREBLIZ.

ELEMENTS OF PRACTICAL CONSTRUCTION, FOR THE USE OF STUDENTS IN ENGINEERING AND ARCHITECTURE. Part I. Structures in Direct Tension and Compression. With Atlas of plates and woodcuts. By SAMUEL DOWNING, LL.D., Professor of Civil Engineering in the Untversity of Dublin. London: Longmans, Green, & Co. Price $7.00. For sale by D. Van Nostrand.

The utility of Prof. Downing's work on "Practical Hydraulics" has been so long recognized by engineering students, that it will be generally gratifying to them to learn he has now completed another work on the same general plan, embracinng the "Elements of Practical Construction;" so far as regards the resistance of materials to direct compression and tension, the subjects of elasticity, indirect compression and tension, transverse resistance and torsion; &c., being reserved for another volume. In treating of each material, a proposition is first given stating its average ultimate resistance; this is followed by experimental proofs, and then are given illustrations, of the materials so strained, taken from completed and successful structures of eminent engineers.

In the first chapter, which treats of the direct resistance to tensile forces, he explains the necessary conditions in good experiments, and points out the importance of the form of the specimen and construction of the apparatus employed. The ultimate resistance of cast-iron to a direct tensile force is about 7 tons per square inch, and is proportional to the area of transverse section in action. The ultimate resistance of wrought-iron to a tensile force is about 20 tons per square inch for boiler plates, and about 25 tons per square inch for the highest quality of rods and bars. Drawn wire under 1-10th in. diameter about 36 tons per square inch. It is mentioned with reference to Mr. Edwin Clarke's table of experiments, made at the Britannia Bridge, that it shows a very great constancy in the ultimate resistance. The ultimate extension, on the contrary, is extremely irregular; indeed, some of the brittle crystalline iron, selected as bad, and which fractured suddenly wlthout much increase of length, actually supported a greater weight than the more fibrous and ductile iron. The professor explains that in appyling to the actual practice of construction the knowledge of the ultimate resisting powers of any material as obtained by experiment, the engineer must in all his designs keep in view the great objects of permanency, stability, and safety; and, therefore, assign to every part such dimensions and form that it shall be acting far within its ultimate power. But the question at once arises, How far within !—what fraction of the ultimate must be the actual resisting force called forth ! For this no absolute rules can be set down; a careful judgment and sagacious use of existing precedents must alone guide us here; a knowledge not only of existing successful works—which from being, as may often occur, stronger than strong enough have, perhaps, purehased the stability at the expense of economy, and are consequently so far not to be followed; but also from the records of past failures, which are in truth but unintended, and expensive experiments.

In subsequent chapters the resistance of timber, direct resistance, to compressing forces, cast-iron and its practical application in compression, wrought-iron and practical application, direct resistance of timber and practical applications, and stone and brick. The direct resistance of stone to a compressive force varies from about 11 tons to ½ ton per square inch, according to the formation from which it has been taken. He remarks that Portland cement, after a rather unpromising commencement, has at length obtained a very high degree of favor with engineers and architects, both on the Continent and in Great Britain, especially in works exposed to water. Compared with Roman cement it has the advantages, first, of being adapted for use both as an hydraulic mortar when mixed with sand in any proportion desired, and secondly, for concrete; also either in foundations, or as backing to front work, and even as grout. It is also claimed for it that it sets harder than the rival cements now nearly supplanted by it, but it has not the property of quick setting as compared with the natural cements, pozzolano, tarras, &c., or the artificial manufactures called Roman, Orchard, &c., cement. There are two appendices, the first treating of the best form of wrought-iron links or bars when resisting tensile strain, and the second containing an extension of Eaton Hodgkinson's tables for the diameters of columns.

It is unnecessary to state with regard to a work of Prof. Downing's that the utmost care has evidently been bestowed upon every portion of the volume, and that the language will make the several matters treated of clear even to the least attentive student, especially as the explanations are rendered still more easy of comprehension by the constant references made to the handsome atlas of plates which accompanies the volume.—*Mining Journal.*

OUTLINES OF PROXIMATE ORGANIC ANALYSIS FOR THE IDENTIFICATION, SEPARATION, AND QUANTITATIVE DETERMINATION OF THE MORE COMMONLY OCCURRING ORGANIC COMPOUNDS. By ALBERT B. PRESCOTT, Professor of Organic and Applied Chemistry in the University of Michigan. New York: Van Nostrand, Murray and Warren streets. Price $1.75.

Since the first appearance, now more than 30 years ago, of Dr. Will's "Outlines of the

Course of Qualitative Analysis followed in the Giessen Laboratory," it has become so customary for students of inorganic analysis to be taught from the moment they enter the laboratory to adopt a defined and scientific method of procedure, usually explained in concise language in a reliable text-book with which they are provided, that the younger chemists can scarcely appreciate the obstacles which the student of half a century since had to encounter in acquiring the knowledge requisite to give him even a decent position in his profession; yet it has been left for Prof. Albert Prescott, of the University of Michigan, to perform to-day a corresponding service for the students of organic analysis, and in doing so he has furnished an outline which, if not perfect, will assuredly form the basis upon which future systematic methods of organic analysis will be built. Well knowing that in so large a field as he has undertaken to cover, the labors of a single investigator would be of comparatively little utility for ascertaining the almost innumerable details which have to be recorded and discussed in treating of the similarities and differences of behavior of the several compounds, Prof. Prescott has wisely availed himself of the researches of all the best authorities, American and European, upon the several classes of substances dealt with, so that full reliance may be placed upon the information which he furnishes.

That organic compounds can be brought into a few and clearly defined groups as readily as inorganic matters or simple elements is not to be pretended; yet classification is no less important, and with the aid of Prof. Prescott's book it will be much facilitated. To give an idea of the manner in which the book is arranged, the first solid non-volatile acids may be taken as a sample. Tartaric acid $H^2C^4H^4O^6$, is described as being characterized by the form of its crystals and its rotation of polarized light (*a*), by its odor when heated, and its color when treated with sulphuric acid (*b*), and so on. It is then explained how it is separated (as free acid) from salts, &c., insoluble in alcohol, from alcoholic solutions, from citric acid, and so on; and it is then stated how it is determined. The several characteristics, modes of separation, and of determination are first given collectively and briefly, and afterwards separately and more in detail, so that the reference is greatly facilitated, the bracketed letters—(*a*), (*b*), &c., being references to subsequent portions of the same numerical paragraph containing the details. Thus turning to the twelfth division of the paragraph (*f*) it is found that free tartaric acid, unmixed with other acids may be determined volumetrically by adding a normal solution of soda to the neutral tint of iitmus. Weighing 7.500 grammes, the required numbers of cubic centimetres of normal solution equals the number per cent. of acid. It is then explained how in the absence of acids forming lead salts it may be precipated, &c., and weighed as normal lead tartrates; when $PbC^4H^4O^6 : H^2C^4H^4O^6 : : 1 : 0.422535$. Similar directions are given for cases where it is expedient to weigh it as calcium carbonate, and for others where it must be determined as potassium bitartrate. These instructions occupy nearly four pages, but from the lucid manner in which the information is given every fact recorded can be referred to at a glance. The succeeding paragraph naturally treats of racemic acid, the isomer of tartaric, and it is explained that racemic is *distinguished* from tartaric as follows:—By forming triclinic crystals, $H^2C^4H^4O^6$, H^2O, soluble in five parts cold water, or 48 parts of alcohol of sp. gr. .809: slightly efflorescent on the surface losing the water of crystalization at 100°. By its solution (uncombined) being able to form after a short time a slight precipitate in solution of calcic sulphate, and a precipitate in solution of calcic chloride; the precipitate of calcic racemate being, after solution in hydrochloric acid, precipitated again by ammonia, that is not soluble in chloride of ammonium solution, by being inactive towards polarized light. The "Outlines" appear to include about 600 substances, most of which are treated with equal completeness.

For the reasons already given Prof. Prescott's volume is necessarily a compilation; but since it is a compilation involving a previously unattempted classification which, moreover, has been made with the utmost judgment, it has probably a greater claim to originality than many other books. After working with his class for several years without other aid than a manuscript digest of directions and references he is convinced, and there are very few who will disagree with him, that a compilation in this subject was desirable—not alone for students in special applications of chemistry, but for the convenience of every analyst. Froximate organic analysis, he remarks, is not altogether impracticable, and organic chemistry is not solely a science of synthetical operations even at present. It is true, as the chief analytical chemists have repeatedly pointed out, that in the rapid accumulation of organic compounds the means of their identification and separation have been left in comparative neglect. It is true also that the field is limitless, but this is not a reason for doing nothing in it. As a result of his labor, Prof. Prescott has produced a work which is well worthy of recognition as a text book both in England and America, and upon the utility and completeness of which he may well be congratulated.

MISCELLANEOUS.

DREDGING FOR AMBER.—According to an official report from Memel, Germany, an establishment has been organized for gaining amber by dredging for it in the Kurische Haff, near the village of Schwarzort, situated about twelve miles south of Memel. It has been known for many years that amber existed in the soil of the Kurische Haff, from the fact that the dredger employed by the Government for the purpose of clearing away the shallow spots near Schwarzort, which impeded navigation, brought up pieces of amber which were duly appropriated by the laborers, and at the time no particular attention was paid to the matter.

VAN NOSTRAND'S

ECLECTIC

ENGINEERING MAGAZINE.

NO. LXXVIII.—JUNE, 1875.—VOL. XII.

THE NEW METHOD OF GRAPHICAL STATICS.

By A. J. DU BOIS, C. E., Ph. D.

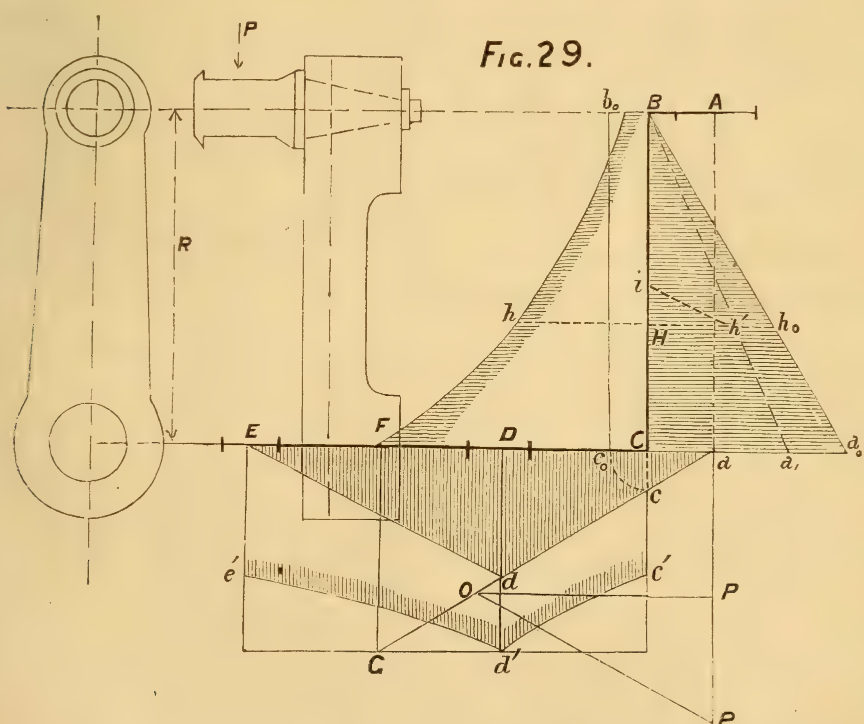
Written for Van Nostrand's Engineering Magazine.

5TH. APPLICATION TO CRANK AND AXLE.

The above finds special and important application in the case of the *crank* and axle.

Thus in Fig. 29, let E D C B be the centre line of crank and shaft. Lay off a P equal to the force P acting at A, choose a pole O and draw O a, O P and

Fig. 29.



the parallels O a and a E. Join E and d, and draw O P_1 parallel to E d. Then P P_1 is the downward force at E, and $P_1 a$ the upward reaction at D. The ordinates to E d a, to pole distance O P give the bending moment for the shaft. Make a F equal to the lever arm R, then F G is the moment P R, and we unite this as above with the bending moments, and thus find the curves c' d' e' the ordinates to which give the combined moments at every point of the shaft. [See 4th.]

For the arm B C make the angle a_0 B C equal to D a d, and then the horizontal ordinates to a_0 B give the bending moments for the arm. Make C c_0 equal to C c, and we have the *torsion rectangle* C c_0 b_0 B, and, as in the previous case, we unite the two and thus find the curve b_0 h F, the horizontal ordinates to which from B C give the required combined moments to pole distance O P. Thus $h' h_0 = \frac{3}{8}$ H h_0, H $i = \frac{5}{8}$ B b_0, and H $h = h_0 h' + h' i = \frac{3}{8} M_b + \frac{5}{8}\sqrt{M_b^2 + M_t}$.

The application of the method, when the crank is not at right angles to the shaft, as also when the crank is double, and generally in the most complicated cases, is equally simple and satisfactory. Our space forbids any more extended notice of these applications, and we must refer the reader to *Der-Constructeur*, by *F. Reuleaux*, *Braunschweig*, 1872, for further illustrations and applications of the method to the solution of various practical mechanical problems.

42. CONTINUOUS LOADING—LOAD AREA.

Thus far we have considered only concentrated loads. But whatever may be the law of load distribution, if this law is known, we can represent it graphically by laying off ordinates at every point equal by scale to the load at that point. We thus obtain an *area* bounded by a broken line, or for continuous loading, by a curve, the ordinates to which give the load at any point. This *load area* we can divide into portions so small that the entire area may be considered as composed of the small trapezoids thus formed. If, for instance, we divide the load area into a number of trapezoids of equal width, as one foot one yard, &c., as the case may be, then the load upon each foot or yard, will be given by the area of each of these trapezoids. If the trapezoids are sufficiently numerous we may consider each as a rectangle whose base is one foot or one yard, &c., as the case may be, and height is the *mean* or *centre height*. The weight, therefore, for each trapezoid *acts along its centre line*. We thus obtain a system of parallel forces, each force being proportional to the area of its corresponding trapezoid, and equal by scale to the mean height or some convenient aliquot part of this height.

We can then form the *force polygon*, then choose a pole, draw lines from the pole to the forces, and then parallels to these lines, thus forming the *string* or *equilibrium* polygon, and so obtain the graphical representation of the moments at every point.

Since, however, the polygon in this case, approximates to a curve, that is, is composed of a great number of short lines, the above method is subject to considerable inaccuracy, as errors multiply in going along the polygon.

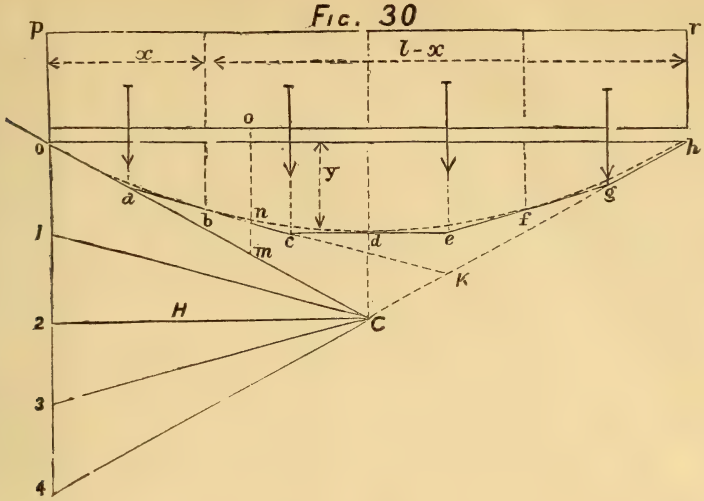
This difficulty can, however, be easily overcome. Thus we may divide the *load area* into *two* portions only, and then draw the force and equilibrium polygon, considering each portion to act at its centre of gravity, and so obtain an equilibrium polygon composed of three lines only. These lines *will be tangents* to the equilibrium curve. We thus have three points of the curve, and its direction at these points. In this manner we may determine as many points as may be necessary, without having the sides of the polygon so short or so numerous as to give rise to inaccuracy.

43. The above will appear more plainly by consideration of a

BEAM UNIFORMLY LOADED.

The curve of load distribution is in this case a straight line. The load area is a rectangle, and hence the load per unit of length is constant. Let us now divide this load area (Fig. 30) into *four* equal parts, and considering each portion as acting at its centre of gravity, assume a scale of force, and draw the force polygon. Since in this case, the reactions at the supports must be equal, we take the pole C, in a perpendicular to the force polygon at the middle point.

FIG. 30



This causes the closing line of the equilibrium polygon to be parallel to the beam itself, which is often convenient. We now draw Co C1, &c., and then form the polygon *o a c e g h*. The lines *o a*, *a c*, *c e*, &c., of this polygon are *tangent to the moment curve*, at the points *b d f*, *o* and *h*, *where the lines of division prolonged meet the sides.* The curve can now be easily constructed as will appear from the next article.

44. MOMENT CURVE A PARABOLA.

Suppose we had divided the load area into only *two* parts, of the length x and l-x (Fig. 30). Then the moment polygon would be *o a k h*, and the horizontal projection of the tangent *a k* would be $\frac{1}{2}x+\frac{1}{2}(l-x)=\frac{1}{2}l$.

That is the horizontal projection of any tangent to the moment curve is *constant.* But this is a property of the *parabola*. *The moment curve for a uniform load is therefore a parabola, symmetrical with respect to the vertical through the centre of the beam.*

If then we divide *o* C and C *h* into equal parts, and join corresponding divisions above and below, we can construct any number of tangents in any position.

[*Note.*—We may prove analytically that the moment curve *is* a parabola, and hence that the line *a k is a tangent.* Thus the moment at any point is

$$Hy=\tfrac{1}{2}plx-\tfrac{1}{2}px^2$$

p being the load per unit of length, l the length, and the reaction at support therefore $\frac{pl}{2}$. Hence $y=\frac{p}{2H}(lx-x^2)$ for origin o.

When the origin is at d, representing horizontal distances by y' and vertical by x', we have $x=\frac{l}{2}-y'$, and $y=h-x'$ h being the ordinate at middle$=\frac{pl^2}{8H}$ hence by substitution

$$h-x'=\frac{p}{2H}\left(\frac{l^2}{2}-ly'-\frac{l^2}{4}+ly-y'^2\right)$$

or reducing

$$y'^2=\frac{2H}{p}x',$$

which is the equation of a parabola having its vertex at d.]

We may of course take the pole anywhere, and hence H may have any value. It is in general advantageous in such cases (*i. e.* for uniform load) to take $H=\frac{pl}{2}$. We have then

$$y^2=lx$$

and for $y=\frac{l}{2}$ or for the middle ordinates we have $\frac{l}{4}$

To draw the moment curve we have then simply to lay off the middle ordinate equal to $\frac{1}{4}$th the span. The curve can then be constructed in the customary way for a parabola. Any ordinate to this curve multiplied by $H=\frac{pl}{2}$ will then give the moment at that point.

Enough has probably now been said to illustrate the application of our method to the determination of the moment of rotation, bending moment or moment of rupture. The reader will have no difficulty in applying the above principles to any practical case that may occur.

It will be observed that the customary curve of moments in the graphic methods at present in use, comes out as a *particular case* of the equilibrium polygon.

This polygon has other interesting properties which we shall be unable to touch here. For instance, just as its ordinates [Fig. 30] are proportional to the bending moments or moment of rotation, so also its *area* is proportional to the moments *of* the moments or the *moment of inertia* of the load area.

As to the *shearing force* at any point of a beam submitted to the action of parallel forces, the reactions at the ends being easily found as above by a line parallel to the closing line in the force polygon, we have only to remember that the shear at any point *is equal to the reaction at one end minus all the weights between that end and the point in question.*

Thus for a uniformly distributed load we have simply to lay off the reactions equal to one-half the load above and below the ends and draw a straight line, which thus passes through the centre of the span. The ordinates to this line are evidently then the shearing forces. If we have a series of concentrated loads we have a broken line similar to $A'_1\ 1'$ $1''\ 2'$, &c., Fig. 32, where each successive weight as we arrive at it is subtracted from the preceding shear.

44. BEAM CONTINUOUSLY LOADED, AND ALSO SUBJECTED TO THE ACTION OF CONCENTRATED LOADS.

In practice we have to consider not only a continuously distributed load, such as the weight of the truss or beam itself, but also concentrated forces, such as the weight of cars, locomotives, &c., standing upon or passing over the truss.

In Fig. 31, we have a continuous loading represented by the load area $A\,a\,c\,b\,B$, and in addition four forces $P'_{1\text{-}4}$. Now since the total moment about any point is equal to the sum of the several moments, we can treat each method of loading separately, and then combine the results. Thus with the force polygon (*b*), we obtain the equilibrium polygon $A'\ 1\ 2\ 3\ \ldots\ B'$ for the continuous loading, and with the force polygon (*a*) the equilibrium polygon $A'\ 1''\ 2''\ 3''\ \ldots\ B''$ for the concentrated loads. If now in (*b*) we draw C L parallel to the closing line $A'\,B'$, and in (*a*) $C''\,L'$ parallel to the closing line $A'\,B''$, we obtain at once the reactions at the supports for each case.

Thus for continuous loading, we have $L\,o$ for reaction at A, and 10 L for reaction at B; for the concentrated loads $L'\,o'$ at A and $4'\,L'$ at B. These reactions hold the beam in equilibrium.

For any cross section *y*, the *shear* to the right is composed of the two components L 7 and $4'\,3'$ (*i. e.* equal to the reactions, minus the forces between cross-section and support). The moment of L 7 is given by the ordinate *o y* to the corresponding polygon, and we may consider L 7 as acting at the point of intersection *a* of the side 78 with $A'\,B'$ (Art. 38). In the same way $L'\,3'$ acts at *b*. We may unite both these reactions and find the point of application of their resultant *c*, by laying off in force polygon (b), 7 *b* equal to $L'\,3'$, and then constructing the corresponding equilibrium polygon *e a d c*. The resultant R passes through *c*. This construction remains the same evidently, even when the points *a* and *b* fall at different ends of the beam, as may indeed happen. The components will then have opposite directions, and must be subtracted in order to obtain the resultant.

The *total* moment of rotation at *y* is proportional to the sum of *m n* and *o y*. The greatest strain is where the sum is a maximum. In order to perform this summation and ascertain this point of maximum moment it is advantageous to construct another polygon instead of $A'\ 1''\ 2''$, &c., whose closing line shall *coincide* with $A'\,B'$. This is easy to do, by drawing in force polygon (*a*) $L'\,C'$ parallel to $A'\,B'$, and taking a new pole C' the same distance out as before, that is keeping H constant, and then constructing the corresponding polygon A′ 1′ 2′ 3′, &c.

Thus the ordinate py gives the total moment at y. We can make use here of the principle that the corresponding sides of the two polygons must intersect upon the vertical through A′ (Art. 26). We have thus the total moment at any point and can easily determine the points of maximum moment or cross-section of rupture. This point must necessarily lie between the points of maximum moments for the two cases, or coincide with one of them. In the figure this point coincides with the point of application of P'_2.

45. CASE OF UNIFORM LOAD.

If the continuous load is *uniformly distributed*, we can obtain the above result without being obliged to draw the curve. As in this case, we have a very

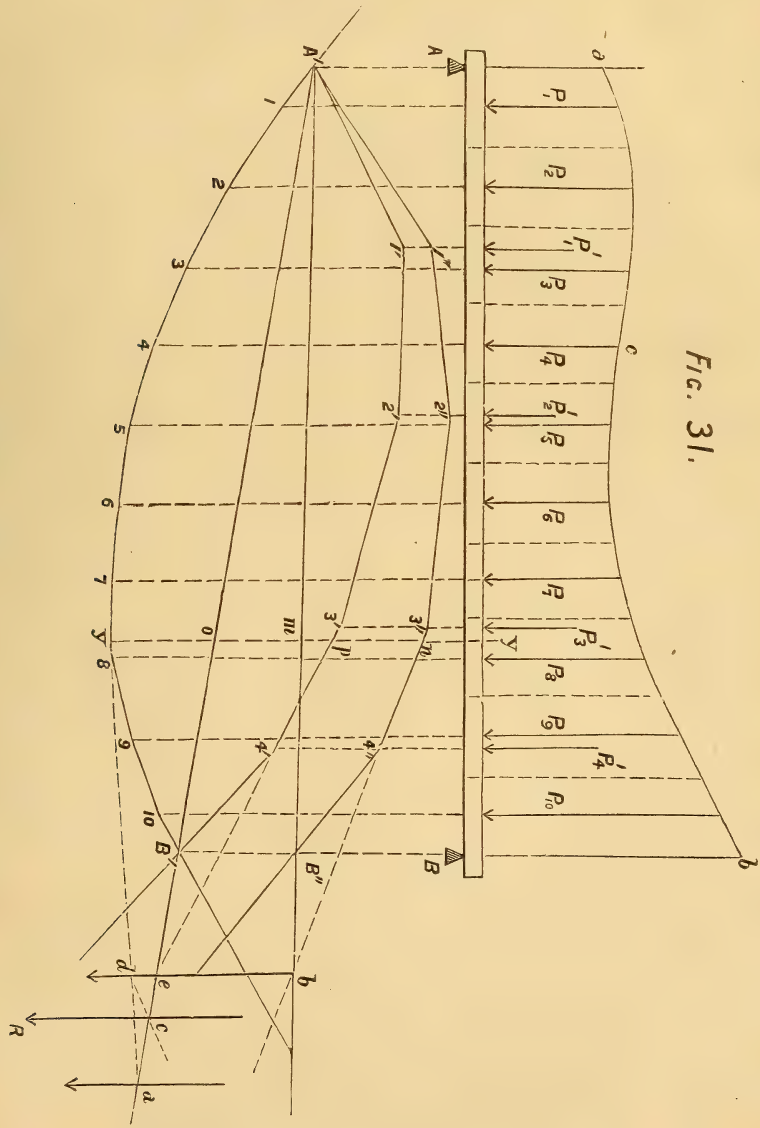


FIG. 31.

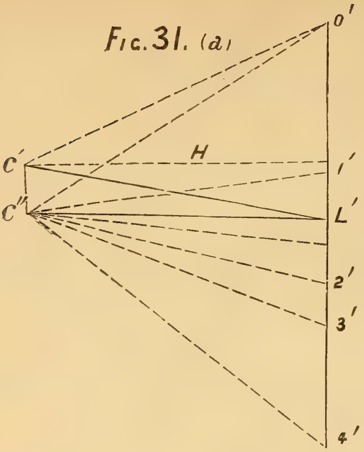


Fig. 31. (a)

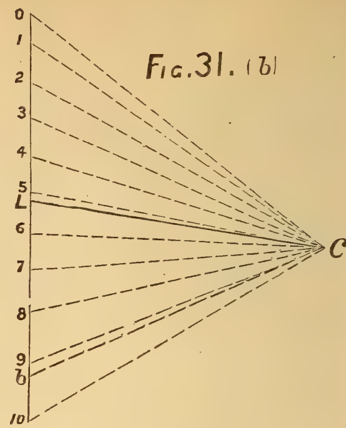


Fig. 31. (b)

short construction for the determination of the point of greatest moment, it may be well here briefly to notice it.

If we erect ordinates along the length of the beam as an axis of abscissas, equal to the sum of the forces acting beyond any cross section, the line joining the end points of these ordinates has a greater or less inclination to the axis, according as the uniform load is greater or smaller. At the points of application of the concentrated loads, this line is evidently shifted. Since at the point of maximum strain the sum of the forces, either side is zero, this point is given by the intersection of the broken line thus found with the axis.

Thus, in Fig. 32, let A B be the beam sustaining a uniform load, and also the concentrated loads P_1 P_2 P_3 P_4. The reaction of the uniform load at the supports is equal to half that load. To find the reactions for the concentrated loads we draw the force polygon 0 1 2 3 4, choose a pole C, then construct the equilibrium polygon A′ 1 2 3 4 B′, and parallel to A′ B′, draw C L ; L 0 and L 4, are the reactions at A and B. Now through L draw A_0 L horizontal, make it equal to the length of the beam, and take it as axis of abscissas. [It is of course advantageous here, to lay off the forces along the vertical through B—then A_0 falls in the vertical through A and 1_0 2_0 3_0 4_0 are under the forces themselves.]

The ordinate to be laid off at A_0 is equal to L 0 + half the uniform load. Between A_0 and 1_0 the line A'_1 1′ is inclined to the axis at an angle depending upon the uniform load. Lay off L U equal to this load, and draw A_0 U, A'_1 1′ must be parallel to this line. At 1′, the line A'_1 1′ is shifted to 1″, so that 1 1″ is the load P_1. Then 1″ 2′ is parallel as before to A_0 U and 2′ 2″ is the load P_2, and so on. *The intersection* 2_0 *with* A_0 L *gives the point of maximum moment or cross section of rupture.* The force P_2 at this point in our figure is divided, as shown by L in the force polygon into two portions, one of which is to be added to the forces left, the other to the forces right. The ordinate $y_0\,y'$ at any point, gives the *shear* or sum of the forces acting at that point. This force acts up or down according as the ordinate is above or below the axis.

Moreover, the area between the broken line and axis A_0 L, limited by this ordinate, gives the *moment of rotation* of the forces beyond the section *y*, areas below the axis being negative. For a section at Z we have therefore A_0 A'_1 1′ 1″ 2′ 2″ *minus* 2_0 2″ 3′ 3″ Z′ Z_0, or what is the same thing, the area Z^0 Z′ 4′ 4″B'_1 L, since the sum of the moments of all the forces is zero.

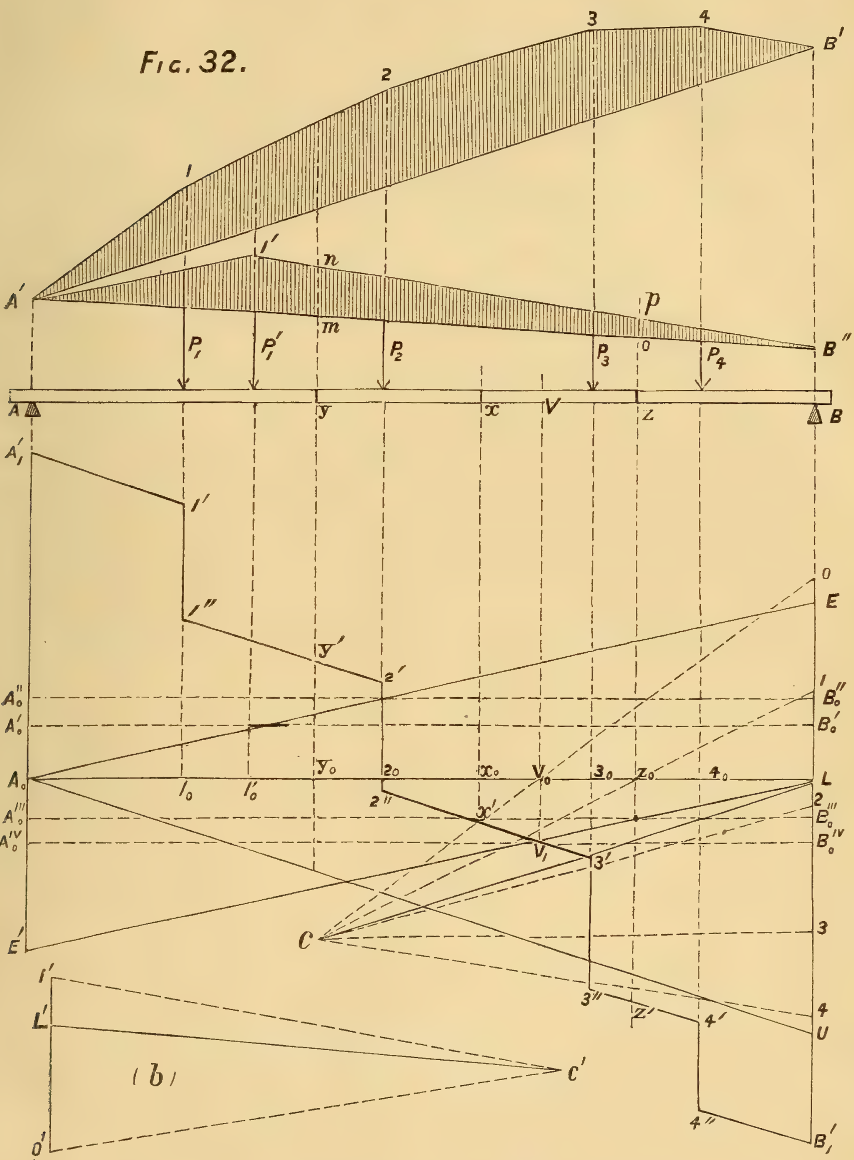
46. INFLUENCE OF A CONCENTRATED LOAD, PASSING OVER THE BEAM.

If in addition to the already existing uniform and concentrated loads, a *new* force operates, we have by (44) simply to construct for this new force its force and equilibrium polygon, and unite the forces and moments thus found with those already existing.

In Fig. 32, we have assumed a new force P'_1 near the left support. The force polygon is $0' 1' C'$, the pole distance being taken the same as before. For any one position of this force, we have then the equilibrium polygon $A' 1' B''$, and drawing a parallel $C' L'$ to $A' B''$ we obtain the reactions $0' L'$ and $L' 1'$, which must be added to the reactions already obtained.

If now we take a section *y between* P'_1 and the point of maximum of moment

FIG. 32.



2_0 before found, the sum of the forces either side of this section undergoes the following changes. Upon the side where P'_1 lies, and the point 2_0 does not lie, where therefore the sum was originally an upward force, we have the downward force $L' 1'$ (equal to algebraic sum $L' 0' + 0' 1'$). The sum of the forces at the section, or the shearing force is therefore *diminished.*

The total rotation moment is, however, *increased* by the amount indicated by *m n*. Both changes, that of the sum of the forces and the moment of rotation *increase* as P'_1 approaches *y*, and are, therefore, greatest when P'_1 reaches *y*.

If P'_1 passes *y*, this point is in the same condition as Z with reference to the former position of P'_1; that is the force and point 2_0 are now both on the same side of the section. For Z then, the original downward force to the left is increased by the force L′ 1′. To the right the upward force is increased by 1′ L′. In like manner the moment of the forces beyond Z is increased by the amount indicated by *o p*. This change is greatest when P'_1 reaches Z.

Therefore when a load passes over the beam the sum of the shearing forces is *diminished* in all sections between it and the original point of greatest moment, and *increased* in sections beyond this point, while the moment of rotation, or bending moment, for all cross sections is increased. These changes, moreover, increase for any section as the load approaches that section. The shear at any point is therefore least, and the moment greatest, when the load reaches that point. As soon, however, as the load passes this point, the shear passes suddenly from its smallest to its greatest opposite value, and then diminishes as the load recedes, together with the moment of rotation. On the other side of the point 2_0 of original greatest moment, the shear and moment increase as the load approaches, and become greatest for any point when the load reaches that point. At the moment of passing, these greatest values pass to their smallest values, and increase afterwards as the load recedes.

Since, by the introduction of the load, the shear for points upon one side of 2_0 is diminished (between 2_0 and the load), and on the other side increased, and the greatest moment is at the point where the shear is zero, it follows that the point of greatest moment moves in general towards the load. At a certain point then, both meet. As the load then advances this point accompanies it; passes with it the original position, and follows it up to the point where it would have met the same load coming on from the other side. From this point, as the load continues to recede, it returns, and finally reaches its original position as the load arrives at the further end.

It is evidently of interest to learn the position of these two points, where the load meets and leaves the point of greatest moment or cross section of rupture, and this, in Fig. 32, we can easily do.

When P'_1 arrives at $1'_1$ we have evidently the reactions by laying off L E equal to P'_1, drawing A_0 E and through its intersection with the vertical through the weight drawing the horizontal $A' B'_0$, $L B'_0$ is then the increase of reaction at B due to P'_1. The entire reaction is $B'_0 B'_1$, and the broken line A'_1 1′ 1″, &c., holds good still if we merely change the axis from A_0 L to $A'_0 B'_0$. The point of greatest moment, which is still the intersection of the broken line with the new axis in the present case is not changed by reason of the overpowering influence of P_2. It does not move to meet the load, but awaits it until it reaches P_2, and until therefore the new axis takes the position of $A_0'' B_0''$.

If, however, the force P'_1 comes on from the *right*, we have the reactions for any position as Z, by laying off $A_0 E'$ equal to P'_1, drawing L E′, and then the horizontal $A_0''' B_0'''$ through the intersection of L E′ with the vertical through Z. Then $A_0 A_0'''$ is the reaction at A due to this position of the load. The intersection *x*′, corresponding to *x*, shows the point to which the point of greatest moment 2_0 moves to meet the load. As the load passes towards the left this point moves towards the right, and both come together evidently at the point V_1, corresponding to the new axis $A_0^{IV} B_0^{IV}$. The point of greatest moments passes them from 2_0 to V_0, and beyond these two limits it can never pass.

Our construction then, is simply to lay off the load in opposite directious perpendicularly from each end of the axis A_0 L, and join the end points A_0 E and L E′. The intersections of these lines with the diagram of shear, give the points 2_0 and V_0 required.

47. The above comprises all the general principles of the subject, that under the limitations as to illustration and space necessary in a series of magazine articles like the present, are capable of presentation. To adequately present the subject under such limitations is, indeed,

impossible. The entire subject of the continuous girder, as also of the moment of inertia, and the application of the method to braced and stone arches, &c., &c., we are obliged to pass over merely with this mention of the fact that, by the aid of the graphical method, we have a practical and easy method of solution which brings fairly within the reach of the practical engineer and builder these and many other important structures, the investigation of which has hitherto demanded the application of the higher analysis, and given rise to methods which can be understood and used only by well versed mathematicians.

The purpose of these articles is avowedly merely to call attention to the method. To give even a general outline of the subject, so as to convey an accurate idea of its methods and advantages was found impossible. We have preferred, therefore to lay down some of the most important principles of the subject, leaving it to the intelligence of the reader to make the various applications, rather than to give those more practical constructions which, for want of such preparatory development of the principles involved, would have been unintelligible.

This must serve to excuse the apparently unpractical character of these last two arts. Upon the basis thus provided we can now give many very easy solutions of important practical problems. Such illustrations, should time and opportunity permit, we may hereafter give.

That a subject which has been so thoroughly systematized, and is of such practical value, should have been so completely ignored by American and English authors is a matter of regret. We can only refer the reader to the works of *Culmann*, *Bauschinger* and *Winkler*, as the best German treatises, and to a work of our own upon the subject, which will shortly appear, in which we have endeavored to treat the subject in as elementary a form as possible, noticing fully all the most important practical applications.

TOPOGRAPHICAL SURVEYING AND KEEPING SURVEY NOTES.*

By RICHARD P. ROTHWELL, C.E., M.E.

The communication which I have to lay before my fellow-members of the Institute, is no elaborate paper, nor the statement of any great discovery; it is simply the record of convenient methods of conducting topographical surveys, and of keeping the notes of the same ; methods that have grown out of practical experience, and have saved me many a day's labor by facilitating office and field work, and at the same time secure a greater degree of accuracy than is obtained by the methods now in general use.

I assume it as granted that no topographical map is worthy of the name, except it represent the elevations and depressions of the service by means of horizontal or contour lines.

In the Ordinance Survey of Great Britain, the contour lines are traced for every fifty feet vertical height, I believe, by running out the line with level and compass through all its meanderings on the surface; this, of course, is a very tedious, though accurate, process, but "in the woods," where many of our surveys have to be made, it would be practically impossible.

Some time ago, I made an extensive and quite elaborate topographical survey and contour map of the southern portion of the Cahaba coal field, in Alabama, the object of the survey being to determine the best route for a railroad to enter the coal field, and open that portion of it where the quality of the coal and the size of the beds made it desirable to open mines. The country is greatly broken by ridges and valleys running in every direction, so that it is exceedingly difficult to select the *best line* in all

* A paper read before the American Institute of Mining Engineers at Hazleton, October, 1874.

respects, for, while it is easy enough to find the best place to cross any one ridge, it is by no means easy to find the line that, though perhaps not the best in crossing any one obstruction, will yet give the best mean results. This could only be done by having a complete contour map of the district, such a map being also essential to the intelligent selection of the best point at which to open mines.

As many of the engineers present know, the financial limits set to such work are, in this country, and especially in the south, very restricted. We have to combine speed and economy with accuracy in such work.

The State of Alabama has its lands divided up into Townships, Ranges, and Sections, by lines running north and south and east and west. I made these section lines, one mile apart, the main lines of my survey, and ran them in some cases with the Transit, reading both deflections and needle back and fore sights, and in other cases simply with the surveyor's compass. In the total absence of any magnetic attraction I prefer the compass. My distances were most carefully measured, with either a brazed link steel chain or with a steel tape, and a stake was driven every hundred feet. These stakes were at least eighteen inches high (so as to be easily found in the brushwood), and were marked as in railroad work, the distance on one side, and at all desirable points with the elevation above tidewater on the other side. Thus X. 87+50 marked on the front of the stake, and 735.62 on the opposite side being X line station, 8,750 feet from the starting point, and the elevation of the surface at this point is 735.62 feet above the sea. The leveling is done carefully, and checked by cross lines. These section lines are approximately North and South and East and West, though not quite straight nor uniform in their variation, owing to errors in the original survey.

The survey is tabled by latitudes and departures, and can thus be plotted on ordinary cross-section paper, without the use of protractors. The lines on the paper being taken as magnetic meridians and east and west lines.

The notes of section lines are kept in the manner prescribed by law. The level man as he runs over them, if thought desirable, sketches in the contour of the surface for a few hundred feet on each side of his line; this, however, is not necessary, as the work is done in a subsequent operation.

We now assume some convenient corner as a zero, or starting point, plot in the section lines on the cross section paper, by latitudes and departures, taking the lines on the paper as magnetic meridians and east and west lines. Those passing through the starting point are the zero meridian and zero east and west line. If we make our map, and the note books, on the scale of 500 feet to the inch (a very convenient scale in extensive surveys), every tenth line (heavy lines), on the paper will be marked as we recede from the zero lines, thus: 5 E., 10 E., 15 E.; 5 W., 10 W., 15 W., etc.; 5 S.' 10 S., etc.; so that any point in the district may be designated by a name which indicates, without a moment's consideration, exactly where it comes on the map; thus, 65 E., 15 N. is a point 6,500 feet to the east and 1,500 feet to the north of the zero point of the survey.

To get the topography, I run lines 500 feet apart, either North and South or East and West, but not in both directions over the same ground. These lines commence at some station on the section lines, and are run due North and South or East and West on the 500 feet lines. They are run with the pocket compass and steel tape or chain, and with the Locke pocket level. These lines close on the section lines, and a check is thus given to the work at intervals of one mile; as the section lines are staked every 100 feet, and the elevation marked on the stakes, the check is perfect and immediately applied, for when commencing the line the man in charge knows exactly when he should intersect the next section line. If he does not strike this point, he can at once verify his work.

With careful work, the variation in direction of the line run a mile with the pocket compass will never exceed 10 feet, and will generally be within 5 feet, either of which is as close as we can plat on the scale used. The levels run over these compass lines with the pocket or Locke level will seldom vary 5 feet in running a mile over rough ground, errors balancing; and as they check up on the section lines every mile, this error can be reduced to say 2½ feet midway between the section lines.

The notes of the survey are kept in a note-book made of X section paper ruled the same on both sides.

We write from bottom up. Thus we will write at foot of page:

"*Running line* 17 *N.*"—We see at once the line being run is an east and west line, at 1,700 feet north of the Zero E. and W. line; we commence at say, "35 E." on this line—that is, at a point 3,500 feet east and 1,700 feet north of the Zero or initial station of the survey. We know, without looking to another line, exactly where our starting point is on the map, and can, without a moment's hesitation, point it out.

After running 500 feet, we find the station is 40 *E*, so that the line is being run *east;* the topography is sketched on as the work proceeds, the field-book in scale and fullness being a finished map, the final map being merely the transfer on to a single sheet, in a better style, of the several pages of the note-book.

The surveying party consists usually of but five persons, three of whom may be green boys.

1st. Axe-man, who is also flagman.
2d. Compass-man.
3d. Front chain-man.
4th. Level-man, who is also rear chain-man.
5th. Rod-man.

If the timber is thick, it may require a second axe-man to be able to clear the line as fast as the level-man can get his notes and sketch in the topography.

The advantage of this manner of conducting a survey are speed, economy, and *accuracy*, for no error can extend beyond a mile, and the notes are all made and map finished *on the ground* with every feature before the eyes of the draftsman, so that if his work be not correct, he knows it at once before leaving the field, and can seek and find the error with but little loss of time.

At night, and during wet days, the work is all "posted up" on sheets of cross-section paper, so that the entire map is complete before leaving the camp, and, in fact, each day's work is complete in itself; and if the survey be suddenly interrupted, as was that to which I referred above, none of it is lost, but it can at any future time be taken up just where it was left off without any difficulty. The notes do not need the presence of the man who made them to interpret them, as is not unfrequently the case. and tell where his line comes on the map; for each page tells itself exactly where it belongs, and as it is itself the complete original of the map containing every contour and feature of the surface, as sketched and figured on the spot, it leaves nothing to the artist's imagination.

The rate at which a party, such as above enumerated, will run out and level these secondary lines depends on the nature of the country. In broken ground, where the brushwood is not too thick, from 7,000 to 15,000 feet of line per day can be run, putting in contour lines every 10 feet vertical, and sketching for about 300 feet on each side of the line. If the lines are run 500 feet apart, this allows an overlap of 50 feet, which serves as a check in bringing the work together on the sheets. The thousand little practical details that facilitate the work, and which suggest themselves naturally to the engineer in the field, are not here mentioned; it is sufficient to call attention to the general outline of the method, and to say that its practical usefulness has been fully proved, for it has been the outgrowth of an extensive experience.

THE CIRCULAR IRON-CLADS OF RUSSIA.

By Admiral POPOFF, Imperial Russian Navy.

From "Naval Science."

I shall begin with a short historical sketch of the circumstances which induced the Admiralty to decide upon the construction of circular vessels. At the time of the creation of the Russian fleet we had in view the unavoidable struggle with our neighbors for the purpose of obtaining for ourselves a free use of the sea. These neighbors were the Swedes and the Turks, and our aim at that time was the possession of an offensive fleet. The question of having a defensive one had then no serious importance, as, in the first place, our coasts, in their limited extent, could have been easily defended by the fleet we had, not to mention the trusty ally we had in the very situation of our seas. Such straits as the Bosphorous, Dardanelles, Sound, and Belt, presented to the sailing vessels of the time very serious obstacles in the difficulties of the navigation and in the strength of the currents. Secondly, international relations had not at that time been so highly developed as they now are, and therefore we had no fear of being engaged in a war with a coalition of other States. Times and circumstances are now quite changed. We are no longer under the necessity of waging an offensive war, while we must be always prepared for a defensive one. Our natural allies for defence — the Dardanelles, Bosphorous, Sound, and Belt—have lost their importance through the introduction of steam, and the development of international relations warns us that instead of one we should be ready to meet many enemies. Experience had already taught us this lesson in 1853. Our fault, during that war, consisted in steadily continuing to adhere to the former system, and in keeping in the Black Sea as well as in the Baltic offensive fleets exclusively. But these fleets proved to be very indifferent weapons in our struggle with the allies. Notwithstanding the high degree of technical perfection which the fleets had attained, and the heroic spirit of our seamen, one of the two fleets was detroyed by ourselves, and the other was indebted for its safety to circumstances that were entirely out of its control. Indeed we had a Baltic fleet, but we could make no use of it in our last war. We did not bring that fleet against the enemy, but made an energetic and powerful use of the materials we had at our disposal in the Baltic Sea. We then built seventy-five screw vessels and fourteen armored rafts, providing them with artillery for that time very powerful, and commenced the construction of other screw vessels as well. Seventy-five screw vessels were more than even England could at that time despatch to the Baltic Sea, and there is no doubt that it was owing to this activity of ours alone that the allies could undertake nothing decisive against us in the Baltic. Here, in the Black Sea, we had no such material means, and the result of it is well known to you. Our Black Sea fleet was destroyed by ourselves, although it was perfect of its kind; the enemy took possession of the Sea of Azow, entered the estuary of the Dnieper, and his success would have been, no doubt, still more important if peace had not delivered us from still heavier trials.

When the question arose—What shall we do in the future?—how can we avoid previous faults? then it was adopted as the basis of all other deliberations that it was absolutely necessary for us to create a defensive fleet so powerful that it can resist any coalition. But the question was solved not in this sense only; it was not forgotten what a powerful means of defence is provided by ocean cruisers, especially in case of war with a nation possessing a large commercial fleet. Who does not recollect the results of such activity on the part of the Confederate cruiser "Alabama" during the late American war? The commerce of the United States was reduced through the activity of this cruiser to a desperate condition; North American traders were obliged to sell off their vessels, as the insurance premium became so high that it was impossible to find cargo for them. True it is that, afterwards, by the decision of the International Arbitration Court at Geneva, England had to compensate the United States for the vessels captured by the "Alabama;" but this does not in the least affect the proposition that in a maritime war it is a matter of great importance to have cruisers. The damages and losses that may be sustained by commerce through the presence on the ocean of a hostile cruiser are so great and of such a kind that it is impossible fully to compensate for them. How can we calculate the losses that might be caused, for instance, by a general rise, in such cases, of the prices of freight? The capture of a mail-steamer may shake a whole trade. As to the offensive fleet, of course it would be very desirable ts possess it, as in some cases it might be very useful to us, and especially if we had to wage war with allied States. But such a fleet is most expensive, and depends entirely on the means which the Government can spare for it.

These premises lead to the following conclusions:—Our first and paramount duty is to protect those points of our coast which are of national value. Therefore the most necessary for us is a defensive fleet. In the Baltic, as well as in the Black Sea, it must be of such efficiency as to be capable of holding out against a united fleet, not only of all the European, but it may be also of more distant States. For, being separated from one another by the continent of Europe, both the Baltic and the Black Seas communicate with the seas surrounding Europe, which circumstance, with the present means of intercourse, and with the aid of steam, enables our enemies very rapidly to concentrate all their forces on the one or the other of our seas.

In the interest of the country, in order that during the war we might emerge from a merely passive condition, and make the war burdensome to each of the hostile States, it might be useful to have cruisers, the mere existence of which in the open seas would be enough to produce panics, raise freights, and cause the enemy innumerable losses that cannot be foreseen.

In the last place, of course it is *desirable* to possess an offensive fleet; but it must never be forgotten that such fleet depends entirely on the financial means which the country has at its disposal. And as an offensive fleet, circumstanced as we are, is less necessary than the others, its development may also, without any prejudice to the substantial interests of the State, be left to the future when our budget shall be able to bear the burden of such heavy expenses. The supply of this want cannot be commenced before the first more important and pressing need has been provided against—that is to say, first of all we must make efficient provision for the protection of our coasts. In deciding State questions of the utmost importance we ought not to be governed by sentiment. And if our wishes only were consulted no one probably would refuse to entertain the thought of possessing an offensive fleet. But, as I have already observed, in this we cannot follow the inclinations of our feelings, but must be guided by the suggestions of calm reason.

Wars are waged, not for the purpose of burning a village, pillaging a town, and generally attacking some point of a coast: such depredation is always sure to receive in its own time a deserved punishment. No, war has in view the causing to the enemy more substantial damage than that; and therefore in creating defensive fleets there is no necessity, and, indeed, it would be quite impossible, to make the defence on such an extensive scale as perfectly to protect each particular point of the coast. Thus it is that the whole question lies, not in making a complete defence of all the points of the coast, but in trying to paralyze the efforts of the enemy on such points only as are of serious importance from a strategical and economical point of view. Such a point in the Baltic is, of course, St. Petersburg, and here in the Black Sea, the Straits of Kertch that serve as an entrance to the Sea of Azow, and the estuary of the Dnieper.

It is from this point of view that the Ministry of Marine have devoted their main efforts to the construction of a defensive fleet, which, as a matter of course, must be adapted to the conditions of the locality for the protection of which it is constructed. When the end proposed is thus specialized it is obtained much more easily and fully, and with less expense.

I have already mentioned that in trying to protect the Black Sea coasts it is necessary to make a most careful and efficient protection of only two points—the Straits of Kertch (the key to the Sea of Azow), and the estuary of the Dnieper. These points are protected by fortresses, but fortresses may be taken. Besides, in the Kertch Straits, where we have the strongest fortress, there is the sandbank well known to you all, on which an enemy could easily commence his works, and remain in almost perfect safety from the fire of the fortress. Thus circumstanced we must strengthen our fortresses with plated vessels of small draught, which, by their mobility and possession of a very powerful artillery, would prove a means of real protection for a given locality. The depth of the estuary is 15½ feet, that of the Kertch Straits 14 feet, therefore for an iron-clad in the Black Sea fleet the draught should be less than 14 feet. How can we reduce the draught so much and combine the thickest possible armor with the heaviest artillery, and do all this with the least possible expense?

These requirements were best attained by iron-clads of a circular form. In proof of this I will quote a passage from an article in the *Golos*, which, as you all know, was by no means written with a view of commending these iron-clads. The *Golos* says—"'Popoffka' has the form of a floating right circular cylinder, which evidently was, is, and ever will remain, the type of an iron-clad the most suitable for a thick armor and heavy artillery, combining, as it does, by its geometrical formation, a maximum tonnage with a minimum draught." (*Golos*, 1875, No. 17.) The opponents of these iron clads themselves have been forced to make such an admission. What they have said may be expressed with more exactness in the following manner:—The circular iron-clads have a minimum of tonnage for a given draught, thickness of armor and weight of artillery. But the tonnage is, as you know, the weight of the whole ship. It represents the sum of the weights of metal necessary for the construction, for the armor, for the artillery, and for engines. Manufactured metal has, in a given locality, a certain price, so many roubles per pood. Therefore an iron-clad that has a minimum of weight, while all other conditions are the same, would be the cheapest. If the circular iron-clad built at Nicholaieff has cost more than other ships of ordinary size, but equal to her in power, and constructed in England, this fact does not at all affect the proposition that circular iron-clads are cheaper than the others. This proves only that at Nicholaieff the pood of worked metal costs incomparably more than in England, and does not depend on the form given to a ship. Nicholaieff had not the means necessary for the construction of an iron-clad at the time of the commencement of the "Novgorod." If at that time it had not been decided to construct a circular ship, but one equal to her in strength of ordinary type, it would have cost no doubt much more, because her tonnage would have been much heavier, and therefore both the construction and the conveyance to Nicholaieff would have required more money. One should not forget the wise rule expressed in the Russian adage—"Beyond seas a calf costs but a farthing, but to bring it home costs a crown." To build here such an iron-clad as the English "Glatton," which has 4,915 tons of tonnage, would require to have worked and conveyed here nearly double the quantity of metal that we used on the "Novgorod"—that is to say, it would cost us nearly twice as much money.

As to the efficiency and strength of the circular iron-clads, in this respect also they are not inferior to the strongest among the representatives of the foreign fleets. The truth of this proposition is evident from the following table:

Iron-clads.	Tonnage.	Draught.	Horse-power of the engines.
		ft. in.	
"Tonnerre" } of the French fleet	5,584	21 0	875
"Tempete" } of the French fleet	4,524	17 0	375
"Glatton," English	4,915	19 4	500
"Admiral Spiridoff," Russian	3,868	19 6	400
"Novgorod" (circular), Russian	2,491	13 2	480
New Iron-clad (cirular), Russian	3,550	13 2	640

From this table it will be perceived that the "Tempête" alone has a draught as low as 17 feet, but it was found necessary, in order to supply her with armor of the same strength, to reduce the power of her engine, so that after all she is not likely to have much pre-eminence in speed as compared with the "Novgorod." True it is that the "Tonnerre" possesses very powerful engines, and therefore must surpass by far the "Novgorod" in speed, but then her draught is 21 feet. The artillery of these iron-clads is also inferior to that of the "Novgorod." While on the "Tonnerre" and "Tempête" are placed 10-inch guns, those on the "Novgorod" are of 11 inches, and though the "Glatton" carries guns of 12 inches they are shorter than the guns on the "Novgorod," and weigh only 25 tons, while ours are of 28 tons each—that is to say, they discharge a more powerful fire, and therefore are more capable of piercing armor.

Let us turn now to the comparison of the armor-plating of these iron-clads. The French iron-clads have their armor 11½ inches thick, the "Glatton" 12, the "Novgorod" 9 inches; but, in reality, the "Novgorod" has, as we shall see afterwards, armor-plating of 11 inches thick, and, it may be, even stronger—all depends on the mode of viewing the structure. Strictly speaking, we have not yet obtained sufficient data for the estimation of the strength of the armor with which the "Novgorod" is clad; this, however, does not admit of a doubt—viz., that technically speaking, the thinner the armor-plating is the better it can be finished by the rolling process, and the better finished it is, the greater proportionate power of resistance it possesses. At the construction of the "Novgorod" it was taken into consideration that we had no means of rolling armor-plates 11 inches thick, and for that reason it was decided to cover her with plates 9 inches in thickness, which were within our compass of perfect working, and we could strengthen the power of resistance of the armor with so-called "channel iron" as a backing. The power of resistance in the channel iron placed on the "Novgorod" is equivalent to that of 2-inch armor, and, therefore, we have a right to maintain that the armor of the "Novgorod" is 11 inches thick.

In the case of the "Glatton," towards both the stem and the stern, the armor diminishes by degrees in thickness from 12 to 6 inches. Such diminution is to be met with on all iron-clads. The "Novgorod," on the contrary, has everywhere considerable curvature, while at the same time she possesses all round the same thickness of 11 inches. The decks of the "Glatton" the "Tonnerre," and the "Tempete," are, again, not so well protected as that of the "Novgorod." The second circular iron-clad now in course of construction is a further development of the same principle. Her tonnage is 40 per cent. less than that of the "Glatton," and will cost us, therefore, 40 per cent. less. While the "Glatton" has a draught of 19 feet 4 inches, that of the new iron-clad will be the same as of the "Novgorod"—viz., 13 feet 2 inches; the armor of the "Glatton" is 11 inches thick, and that of the new iron-clad is 18 inches. I may confidently affirm that when the new iron-clad was first laid down no foreign navy possessed a vessel with such strong armor. Now in England they are building the "Inflexible" with an armor of 24 inches in thickess at the water-line; but this is, of course, in consequence of our having decided to give to our new circular iron-clad armor 18 inches thick.

In one of the recent numbers of the English periodical, *Engineering*, a table is given in which the iron-clads of all fleets not English are placed in the order of their capability of being pierced by the English guns. In this table, which begins with the weakest armor, our circular iron-clads stand the third from the end; the "Tonnerre" and "Tempete" are next, and the last among them is the "Peter the Great," whose armor, by-the-bye, is represented to be thinner than it really is. The chief naval architect of the English fleet, at a meeting of the Institution of Naval Architects, held on the 3d of April, 1873, concluded his description of the "Peter the Great," with the following remarks: "The 'Peter the Great' is a long way yet from completion, and the intentions of her designer may not be carried out. We cannot always do what we should like. I hope for the sake of her able designer that she may prove as good a ship as the 'Fury.' I do not wish her to be better, and I dot think she will be better." I cite these words for the following purpose: Meditating on the results obtained by Mr. Reed and Mr. Barnaby, I came to the conclusion that they were got by diminishing to the lowest possible degree the quantity of metal necessary for building the hull of an iron-clad. Following in their footsteps, I have always been faithful to this principle, so that at the construction of the "Peter the Great" we reduced the weight of iron used to the extent of 40,000 poods, which circumstance enabled us to furnish her with 14 inches thickness plating, the same as the "Fury" has, and strengthen it besides with the channel iron backing; thus, though the "Peter the Great" was commenced two years before the "Fury," the former remains still the stronger.

It is said that the circular vessels are the invention of the late Mr. Elder. I think it right to mention this, not that I feel my *amourpropre* wounded in consequence. Most decidedly I do not attach any importance to so-called inventions. All who set themselves to work at the solution of a given problem improve this or that part of it—that is, invent. It is not Elder alone who has worked out the solution of this problem of circular iron-clads; many an officer and engineer has devoted his time to the same object, and each one has brought his mite of labor, knowledge, and talent to its solution. There is, however, a great difference between Elder's form and mine. Elder's vessel below the water-line has the appearance of a segment of a spherical body, while the same part in our circular iron-clads presents the aspect of a cylinder with circularly-shaped ends; this difference is the cause of the "Novgorod" having only 13 feet draught, while in Elder's vessel, notwithstanding her equality to the former in tonnage and diameter, would have sunk to the depth of 23 feet. Besides, as to the rolling and pitching of the vessel, there is also considerable advantage in favor of the design of our circular iron-clads. While the form of Elder's vessel is such that in rolling it does not present any other resistance than that of the friction of the surface, in the case of the "Novgorod" this resistance is greatly increased by her flat bottom.

I turn now to the details. The placing of an open turret on the "Novgorod" was determined by the following considerations: Covered turrets present serious inconveniences. Being rotatory they can, without difficulty, be blocked by a wedge, which it would be much more easy to insert in the turret aperture than to destroy a platform placed in the open turret. Again, the closed turret impedes the view, and, what is still more important, cannot be fired from with precision. Each of the two guns placed in the covered turret has in aiming an error special to itself, notwithstanding that the turret is turned in the direction of one of them; such being the case, one, of course, cannot seriously speak of the efficiency of the firing. I have been deeply convinced of the truth of this ever since I was commissioned to re-arm the four Admirals.* The captains and the officers of our gunnery squadron at Revel share the same opinion. In the open turrets all these inconveniences are remedied, and they were adopted for our circular iron-clads as well on this account as on the following considerations: When the Germans besieged Strasbourg they placed a breaching-battery at the distance of 700 yards from the rampart; they reckoned that with the precision of firing from their siege-artillery they could even at such a distance destroy the walls, while those in charge of their guns would be protected from the enemy's fire; and in view of this latter circumstance they made their battery open, and hence were enabled to increase the angles of the range of their guns, and concentrate a greater part of them on a particular spot. Our circular iron-clads, designed with the exclusive purpose of defending passages already protected by obstacles, appear to be in a position very much like that of the Germans before Strasbourg; having powerful artillery, and remaining behind the bar, it will rest with themselves to choose their distance. During the battle they will always have it in their power to retire to such a distance as to render the rifle-fire directed against them ineffectual; therefore the very principles of sound economy required that

* Four ships named after four distinguished Russian Admirals.

we should not refuse to avail ourselves of the advantages to be derived from open turrets.

We have already laid it down that the more limited the purpose for which the vessel is designed the less will be her cost, and the better she will answer the end and aim in view. Open turrets facilitate the precision of fire, and for that reason we could not but avail ourselves of the advantages they offer.

Ever since open turrets were first introduced the question arose, and is still continually mooted, how to withdraw the guns into the turret after the discharge of the fire. In Russia, Captain Borissoff, of the Engineers, was sent to England for the express purpose of studying different systems of lowering guns. Lieutenant Razskazoff is still there for the same end; and, lastly, there are many who are devoting their time and labor to this question, as Moncrieff, Armstrong, Anderson and others. Captain Borissoff has already prepared a project for causing the guns to recoil; but as there are many technical difficulties in the way, the fitting of his machinery to the iron-clads has been postponed until the final experiment of it has been tried on land.

I have already pointed out to you the fact that by increasing the diameter of the iron-clad now in course of construction by only 19 feet, we were enabled to furnish her with unprecedented armor and artillery—viz., guns of 40 tons 12 inches bore and 18-inch armor. But the same means would have enabled us to obtain other results if we had had them in view. For instance, we could have increased the speed, as the increase of tonnage would have placed us in a position to fit them with more powerful engines. But in view of the particular purpose for which these vessels had been constructed, it was quite unnecessary to give them a greater speed, otherwise we might have dispensed with the 7-inch thickness of plate which is proposed now to be laid above the adopted 11-inch armor. We could then have replaced it by some other weight, as, for instance, more powerful engines as just stated; but there really is no necessity for increasing the speed of the vessel, and, besides, the engines are already ordered. Again, this additional plating might have been employed for other purposes. In its place we could put two more turrets, and protect them by 14 inches plating, and by placing in each turret two 12-inch guns we should have tripled the artillery fire of the new iron-clad. There are no technical difficulties in the way of such an object. The additional armor will not be delivered here before the expiration of three months, and there will be no difficulty whatever in altering it, as we already possess in our dockyards the necessary means for such alterations. It must be borne in mind, however, that the thickness of the armor-plating is increasing every day. The more recently a new vessel is laid down, the thicker is her armor; the English "Inflexible" is to have already 24-inch armor. Besides, the English have commenced the construction of 80-ton guns, against which 11-inch armor is of course too weak; even the 18-inch armor will be sufficient only in view of the special purpose for which the vessel is constructed, as she can retire to a distance sufficient to protect her from the 80-ton guns of the enemy.

At the discussion of the project of circular iron-clads the question of supplying them with rams were also raised. It was decided, however, not to supply the ships with them, and that for the following considerations: In 1868 Captain Koltovsky, the commander of the clipper "Guydamak," which had been fitted with the folding torpedo poles, when on the Transound roadstead, at the time of the Imperial review, blew up while in motion one of the old clippers which was towed by a steamer, and destroyed her at a distance at which no ram could be effective. Since then this branch of warfare has greatly advanced. The Admiralty have given it a proper organization, and have founded a school of marine mining, and, in a word, have placed it on such a firm footing that we cannot but count on a further development of the science. The present application of torpedoes as a substitute for the ram is so simple, and at the same time so sure, that it can be adopted without the slightest risk. Apart from folding torpedoes there already exist others. Finally, in favor of such a decision we have also the circumstance that the ram begins to be effective at a distance of no more than 8 or 10 feet, while the telescopic poles act effectually at a distance of 25 or 30 feet.

At present the inconveniences caused by rams are recognized to such a degree that in England, on the newly-projected iron-clads—*e. g.* on the "Nelson" and others—it is proposed to fit them in such a manner as shall admit of their being taken off and thus got rid of, at least in the time of peace. We might avail ourselves of this adaptation, and if it should be thought necessary to fit our circular iron-clads with spurs there will be no difficulty whatever in doing it by adopting removable prows, and that the more readily as the fitting of such prows is facilitated by the circumstance that our iron-clads draw little water, and it would even be unnecessary to take them into dock for that purpose, it being quite sufficient to raise that part of them where the ram is to be placed by means of air-bags.

It has been said that the "Novgorod" drew more water than was expected according to the original project, but this is not true. Were it really the case, her deck would not have been 18 inches above the water-line, as was projected and as is really the case, as you all know. Nevertheless, the "Novgorod," up to the present moment, has always been more heavily laden than was originally proposed. According to the original project the "Novgorod" was to have only 12 feet draught, exclusive of the keels; after she was sheathed with wood the draught was increased to 12 feet 6 inches without the keels, and with them 13 feet 2 inches. The iron-clad now in course of construction will have just 13 feet draught if I get permission to lessen the depth of the keels by two inches. Generally speaking, though keels serve to a certain extent to diminish rolling, they are chiefly intended to act as a protection against stranding.

The deck-plating on the circular iron-clads is 2¾ inches thick. In the flat part of the deck of the "Novgorod," and that only temporary and to a very limited extent, besides the superstructures the armor is only 1¾ inch thick; but a layer 1 inch thick can at any time be placed above it. The armor for the funnels is also wanting, but it is ready, and can be fixed in a very short time. The whole armor in the "Novgorod" yet wanting weighs no more than 30 tons, while on her trial she had 60 tons of fuel more than was originally proposed; and through this means her qualities were tried on more distant voyages. Therefore in time of war, when all the armor not yet fitted is supplied, she will still be able to take about 30 tons of coal more than originally intended; and should it be necessary for her to keep all the provision of coal until the commencement of the battle, she can be towed to the place assigned to her on the roadstead, in case of need, by our yachts and steamers.

The ventilation of the circular vessels is excellent. Suffice it to point to the fact that in all other iron-clads ventilators are in constant action. Thanks to the general belief that iron-clads require ventilators, one was also fitted on the "Novgorod," but this proved quite superfluous, and the ventilator was never put in motion. Through the openings of the turret deck such a quantity of air passes that this natural ventilation is quite sufficient. I asked the permission of the commander-in-chief to take away the ventilating engines, but for the sake of experiments on the ventilating machinery during the hottest part of summer his excellency desired it to be left till autumn. In all probability it will then be taken off, and then the "Novgorod" will be the only iron-clad in the whole world with a low freeboard and no ventilator. In order that the natural ventilation may act, even when fresh breezes may make it necessary to cover over the turret, in its centre can be placed, as proposed by Captain Koltovskoy, a ventilator of sufficient height, in order that during no weather, however tempestuous, can the spray get into it. This ventilator may be utilized for other purposes also. It is already proposed to supply it with an electrical-light apparatus. Lastly, on the top of it can be placed mitrailleuses, as will be done in the case of the new vessel. The "Novgorod" is ventilated, besides, through the engine-hatches; but it is not likely that even this will be left. We have already tried steaming with closed portholes, and did not observe any change.

On the vessel now in course of construction all ventilation will be effected through the grated bottom of the turret, the ventilating funnel around it, and the central flue.

The circular vessels present many advantages in their simple aud practicable arrangements for pumping out water from the hold, as compared with vessels of ordinary size. This arrangement is already more excellent in the "Novgorod" than in any other vessel. From the drawing here you will see that round the whole inside of the vessel there are placed over her bottom pipes furnished with suctions, which serve the purpose of concentrating all the available means for pumping out water on a damaged part. Besides, for pumping out water in ordinary times—viz., when the water in the hold does not rise above some inches, so that the ejectors cannot already reach it—there is a system of pipes, founded on Downton's principle, leading into each compartment; therefore it is quite enough to turn only the goose-neck of the valves in order to cause the pumps to work in a given compartment. But this problem has been solved in a more excellent manner in the new vessel. The system of pumping out water projected for her may be called perfect. Here the removing valve is to be placed in a particular compartment in the centre of the ship; from it will radiate eight pipes into the water-tight compartments fo the vessel. This is all; but you see how simply and practically all the means of pumping out of any compartment of a vessel can be concentrated by this process. Such a degree of simplicity and effectiveness it is impossible to attain in ships of ordinary type. The length of the pipes, a number of valves and cocks, complicate the system, and do not present in return the assurance that it can be trusted as much as the system adopted for the circular ship.

At first the hawse-holes were placed on the iron-clad deck of the "Novgorod," as, according to the purpose for which she was intended, she was not expected to remain long in the open roads. But when this proved to be the case the hawse-holes were placed higher on the deck of her superstructure. As to the supertructures, they ought to be looked upon as the high bulwarks of a casemated ship, and were constructed exclusively for the purpose of providing the crew with convenient accommodation.

Rolling and pitching in a circular ship are far less perceptible than in any ship of another type. I have sailed in all sorts of ships, experienced all sorts of tempests, and from that experience I have derived my firm belief that no other ship is tossed so little and so quietly as the circular ship, and it is easy to understand this. The flat bottom of the circular ships serves in this case the same purpose as the small round plank of wood used by the water-bearers in their pails, in order to prevent water from splashing, or, in other words, the flat bottom is nothing else but a huge horizontal keel which destroys the action of the waves. With increase of diameter the vibrations diminish, because the bottom increases with it, and the mass also; but the larger the mass of a ship is the more powerful must be the waves to produce oscillation in her. The contrary assertion, that the circular ships are more sensitive to the waves, is founded on a misunderstanding. Looking from a distance, and especially if one has to come up to her in a small boat, when the sea is rough, the fact of her freeboard being deeply emersed and immersed leads some to think that she rolls deeply; but it only appears so, while in reality the angle of her heeling over is not great. It is easy to show by a diagram the difference between the rolling of the "Novgorod" and that of an ordinary brig, the width of which is three times less than the diameter of the "Novgorod," and whose length is equal to her diameter. You see that, although, as it appears, the rise and fall of their sides or bulwarks are the same, the angle of the heeling over of the brig is three times larger than that of the "Novgorod." Besides, an ordinary brig suffers much more from rolling, her stem and stern being something like wedges, which sink deep in the water and float there, being supported by the remaining parts of the the ship, and thus a very considerable strain on the ship is caused; and there is no other form besides the circular which possesses an enormous floating power in its extremities. Therefore the "Novgorod" is naturally subject to pitching in a less degree than a brig; and, as the rolling and pitching are the same in her, she will roll easily in all directions. The low freeboard of circular vessels, in its turn, also helps to diminish the oscillation. That this is the case with monitors as well is a fact so generally known that I need not dwell on it longer. How small the amount of the oscillation of the "Novgorod" is I ascertained personally on her way from Sebastopol to Yalta, on the 9th of September. I cannot say that we met in this passage with unusually tempestuous weather, but the wind was very strong, as is generally the case at that time of equinoctial gales. When we got to the Yalta roadstead, I left her to embark on the "Griklick," which, though she was lying at anchor against the wind, rolled to such a degree that in the cabin where I was the washing apparatus was thrown down; and I remember that at night the rolling of the "Novgorod," steaming against the sea, was so small that in the captain's cabin large candlesticks never fell from the table on which they were placed.

Trying the qualities of the "Novgorod," while she is the only circular ship afloat, and we have not finished our experiments of all kinds, and under all possible circumstances, it is the paramount duty of her captain to dismiss altogether the suggestions of his self-love, and never to expose to danger the ship intrusted to his care, were it at the risk of his good reputation, or at the risk of having denied to him those personal qualities which he really possesses.

It is said that the "Novgorod" is very ungovernable, and in proof of this the fact is adduced that she carried off the buoy when passing through the estuary. In this respect Baron Bistrom is right when, in his article, he observes that in shallow water every ship is ungovernable. The fact of a buoy being carried off cannot be adduced as proof of the ungovernableness of a ship; it can be explained otherwise—namely, that the buoy was touched and carried off by the self-confidence of the captain. Against being ungovernable, strictly so called, the "Novgorod" is furnished with safeguards in her six independent screws, which can be used at pleasure, and which no other ship possesses. But there are many who ascribe the cause of her ungovernableness to this very multiplicity of screws, and affirm that it proceeds from the racing of the screws. This is not true. There was only one occasion on which racing was observed, and this only recently, since the blades were lengthened. In order to control the working of the engines, and to keep the number of revolutions uniform, special instruments—strophometers—were ordered, which indicate the number of revolutions being made by the engines at any moment. And the circumstance of the "Novgorod" possessing six screws, and not one, as is the case with other ships, must be, of course, considered, not as a defect, but as an advantage. It is affirmed that the screws of the "Novgorod" can be easily damaged, as they are not protected by overhangs like those of monitors. But there is no necessity whatever to protect the screws, bearing in mind the special purpose for which the ships are intended; and in case it is found necessary, it will suffice to enlarge a little the stern superstructure, and make it project to form an overhang to protect the screws.

Lastly, it remains for us to examine one more point—the speed of a circular ship. At the time when the circular ships were projected it was required that they should possess a speed not less than that of monitors. It was proposed to make these ships 96 feet in diameter. Afterwards his excellency the commander-in-chief, at the time of his visit to St. Petersburg, wanted them to be sheathed with wood and copper, in view of the circumstance that the comparative saltness of water of the Black Sea would otherwise make it necessary frequently to dock her in order to have her bottom cleaned. It was also thought the armor-plating would be stronger and its working easier if one curvature only were given to it—viz., if the plates were placed vertically—and in order to preserve the outward circular appearance of the shape of the vessel, the space filled up with wood backing. The importance of these propositions, as well as the circumstance that even after the proposed alterations had been made the speed of the "Novgorod" was nevertheless to remain the same—viz., not less than that of monitors—prevented my raising my voice against those alterations. But they increase the diameter to 101 feet, and the displacement by 400 tons, and thus increased the area of midship-section, while the engines remained the same. Notwithstanding all this, the correctness of the preliminary calculations as to the speed was afterwards confirmed, and the "Novgorod" sailed as she was expected, according to the original project, not slower than the monitors.

It is erroneous to affirm that circular ships are not capable of possessing great speed. To prove this it would have been necessary to make experiments with this particular object in view. But not having constructed circular ships for high speed, we had no need to make such experiments. My own personal opinion is that circular ships are capable of possessing great speed. I know that this question is being discussed in England. There is a project for a passenger and goods steamer to run between Liverpool and Birkenhead to which it is proposed to give a circular shape, as this shape is supposed to be able to satisfy the requirements of the enormous traffic in this locality with less expense. The full waterlines of a circular vessel are not an obstacle to obtaining a great speed. This appears from the following fact: You know that of late years small steamboats are of an unusual speed, light hulls, very powerful engines, and deeply-placed screws, have been built. Some of them have made twenty miles an hour. In England such boats have been built by Mr. Thornycroft, and in Russia by Mr. Baird. Mr. Baird's boat was constructed of copper, from the designs of Mr. Norman Scott Russell, the son of a well-known English engineer, who was the first to design and apply the principle of the wave-line. Mr. Russell's son, in order to give the boat a minimum of resistance, availed himself of the principle of the wave-lines discovered by his father. But what is the result? When the boat reaches the maximum of speed the stern and bow come out of the water altogether, so that the keel is exposed to the extent of some feet, and she retains in this position the fullest waterline. If that part of her which floats out of water were cut off, the boat, instead of losing, would gain in speed. This makes me think that the pointed parts of the water-line when the boat is at the utmost of her speed have no importance whatever, and everything depends on the proportionate power of her engines. (Here the admiral showed by means of a diagram that in a circular vessel the power of her engines may be increased to an extraordinary degree, while preserving all her advantages over the ordinary vessels as to the area of her midship section, the surface of friction, the size of her body, and comparative cheapness.) Although it was not intended that the vessel now in course of construction should go faster than the "Novgorod," it is nevertheless very probable that she will do so. In those boats of which I have made mention the screws are placed deeper, and that of course is one of the causes of their high speed. There is no doubt that if the screw works in deep water it will be more effective. And this led to the change in the disposition of the screws in the vessel now in course of construction. The shafts of the two middle screws are lowered, and the diameters of the screws increased, so that these screws work in deeper water, and below the bottom of the vessel; and in order that they may not prove an obstacle in shallow water these screws will be fixed, from their having three blades, in such a position that the blades shall not come out below the bottom. Besides, these large screws will be set in motion each with two engines, while the remaining four of a smaller diameter are to be worked only with one engine each. Mr. Harland, an Englishman, for the same purpose—viz., to be able to change the immersion of the propeller according to the depth of water, proposed to connect the screw-shaft with the crank-shaft by means of a universal joint. With this arrangement, when the vessel comes into shallow water the screw is raised; and then, although the screw-shaft is inclined to the crank-shaft, its rotation will continue the same as before. When in deep water the screw is lowered, it being more advantageous to let it work deeper, so that the two shafts make one straight line. The steamer "Britannique" was the first to adopt this improvement proposed by Harland, and performed the voyage from Liverpool to New York in 7 days 18 hours.

In a word, there are very many means

of attaining a high speed in circular vessels, and that the more easily as their small draught is in this respect a most advantageous circumstance. Of course all this requires a great expenditure of money, but without money nothing can be done. I am not surprised that circular vessels should have opponents, as every new idea is received with doubt. That vessels could be constructed of iron was also doubted. When the "Great Western" was finished it was said she would not be able to cross the ocean, and even when she safely reached America it was still affirmed that she would be obliged to remain there, and that similar vessels would never be constructed in future. Nevertheless, after her there were built vessels of a still larger size, and iron became nearly the only material used in shipbuilding. The same we see now also. It has been said that the "Novgorod" would sink at the very launching; that she would not be able to keep the sea; that she could not be lifted on a hauling-up slip; that on the raising of her stern she would capsize, and so forth. These opinions were shared even by some competent persons. Nevertheless the "Novgorod" was launched and did not sink. When ordered to do so she got to sea, made safe voyages and behaved well, and fired her guns efficiently; she was lifted on to the slip (made, by-the-bye, not especially for her), and nothing happened to the slip, so that after the "Novgorod" was taken off it received the largest steamer that ever had been placed on it. Lastly, she was raised when it was necessary to change the pitch of her screws and did not capsize.

ON SOME REMARKABLE CHANGES PRODUCED IN IRON AND STEEL BY THE ACTION OF HYDROGEN AND ACIDS.

By WILLIAM H. JOHNSON, B.Sc.

From the Proceedings of the Royal Society.

Some three years ago my attention was called to a remarkable change in some of the physical properties of iron caused by its temporary immersion in hydrochloric and sulphuric acids. This change is at once made evident to any one by the extraordinary decrease in toughness and breaking-strain of the iron so treated, and is all the more remarkable as it is not permanent, but only temporary in character, for with lapse of time the metal slowly regains its original toughness and strength. With a view of ascertaining the cause and degree of this change, I have from to time made a number of experiments, some of which were carried out on a large scale in an iron works where quantities of sulphuric and hydrochloric acids are used to remove the coating of oxide from iron wire, preparatory to drawing it. Many of these experiments have been already described in a somewhat desultory form in the "Proceedings of the Literary and Philosophical Society of Manchester," for Jan. 7th, March 4th, Dec. 30th, 1873, Jan. 13th, March 10th and 24th, 1874.

As mentioned before, I first noticed that iron wire became more brittle after a few minutes' immersion (half a minute will sometimes suffice) in a strong hydrochloric or dilute sulphuric acid—a piece breaking after being bent once on itself, while before immersion it would bear bending on itself and back again two or three times before breaking. But perhaps the most remarkable phenomenon was, that if, while still hot from the effort of breaking, the fractured part was wetted, it appeared to froth, copious bubbles of gas being given off from the whole surface of the fracture for 30 to 40 seconds, or even longer, making the water on the fractured surface appear to boil violently. This frothing is increased by anything that augments the heat produced by fracture; in fact it is necessary that the fracture be more or less warm to cause the escape of bubbles; for if the wire be nicked and broken short without generating any heat, few or no bubbles will be seen. By further experiment I found that other acids, such as ascetic, had the same effect on iron as those first used; and it became evident that any acid which liberates hydrogen by its action on iron is able to produce them. Nitric acid, which under usual conditions does not liberate hydrogen by its action on iron, is, however without effect. The frothing the diminution of toughness, and all other changes caused by an immersion in acid are, as a rule, only temporary; for after an exposure to a temperature of about 16° C. for three days, or of 200° C. for half a day, the wire will be found to have regained its original toughness, and no bubbles, or any sign of evolution of gas, will be seen, as before, on moistening the fracture. The bubbles also cease to be visible long before the wire has recovered its original toughness or elasticity. Immersion in water, particularly if warm, hastens the restoration of toughness, and numerous bubbles may be seen to arise from the iron when first immersed. If a little caustic soda, or other alkali, be added to the water in which the iron is laid, its recovery is still further hastened, as it neutralizes a film of acid which seems to adhere to the surface of all iron which has been attacked by acid.

It seems at first remarkable that steel does not froth when fractured after immersion in acid, under the same conditions as will produce a violent evolution of gas with iron; and yet the action of acids on steel is more rapid, more marked, and more permanent than on iron. The decrease in toughness is such that a piece of steel which, previous to immersion in hydrochloric or sulphuric acid, would stand bending on itself and back two or three times, will break short off like a pipe-stem when bent. So great is the influence of acid, in fact, that 10 minutes' immersion in dilute sulphuric acid will sometimes cause a coil of highly carbonized tempered cast-steel wire to break of itself into several pieces while in the liquid.

The amount of carbon in the steel appears, moreover, to be connected with the action of acid; for in mild Bessemer steels, containing about 0.20 to 0.25 per cent. of carbon, the change is very little more marked than in iron, even frothing being apparent after prolonged immersion. With an increased percentage of carbon the action, however, is more marked and of longer duration. Half an hour's immersion in hydrochloric acid will make a piece of steel containing, say 0.60 per cent. of carbon, break with a much darker colored fracture, and render it so brittle that no amount of exposure to the air or heat will ever completely restore it. On hardened and tempered steel the decrease in toughness produced by immersion in acid is greater and more rapid than with the same steel in a soft state.

Suspecting that the absence of frothing on the surface of steel after immersion in acid might arise from the bubbles of gas given off being so small as to be invisible to the naked eye, I examined the moistened fracture of a piece of steel under a microscope with a power of 250 diameters. My expectations were fulfilled, for numbers of minute bubbles were seen to rise from parts of the moistened surface. It appears that the fibrous and open structure of iron allows any gas which has been occluded in its substance to pass more easily to the surface of the fracture than will the close, unfibrous, homogeneous structure of steel; consequently the evolution of gas will not be so rapid with steel as with iron. Moreover, the fracture of steel presents an almost infinite number of small points, all favorable to the rapid evolution of small bubbles invisible to the naked eye. Iron wire, on the other hand, breaks with a fibrous, mossy fracture, which will retain the small bubbles until they have grown sufficiently large to be visible to the naked eye. Hence the frothing in iron and its absence in steel.

The following experiments were made to ascertain if there was any appreciable increase in weight in iron which frothed over the same iron when in its usual state. The pieces of iron and steel wire, after immersion in acid, were well washed in cold water, and when dry weighed, this being the weight when the metal contained the gas. Subsequently they were heated several hours in oven to restore them as far as possible, and again weighed. The result of the last weighing, in every instance, must always have been a little too large, as it was found impossible to prevent a thin film of rust forming on the surface of the metal when being heated in the oven. Notwithstanding this, the results showed in every case a gain in weight after immersion in acid. After five hours' immersion in acid the average gain in weight for mild steel, charcoal iron, and common iron was in

Hydrochloric acid.....	.028 per cent
Sulphuric acid.........	.036 "

The steel gained considerably the most—a result well worthy of notice; for we shall see that the tensil strain and elasticity of steel are far more affected by the presence of absorbed hydrogen than iron under like conditions—probably in part because more gas is occluded by steel than iron (a conclusion which the greater increase in weight of steel, in comparison with iron, bears out), and in part owing to the different molecular structure of steel.

I hope at some future time to ascertain, if possible, if this gain in weight is entirely due to occluded hydrogen, or whether also to absorption of acid to a greater or less extent.

Having examined in detail some of the effects of immersion in acid upon iron and steel, we will now more closely consider them with the object of discovering the cause.

It might at first sight be thought that the frothing could be explained on the supposition that by the action of acid, iron is thrown into what may be called the "active state," in opposition to the so-called passive state caused by nitric acid, and that in this "active state" it is able to decompose water at the ordinary temperature, forming oxide of iron and bubbles of free hydrogen. The facts, however, do not bear out this theory, as the bubbles are still seen if oil be employed instead of water; and no matter how numerous the bubbles, the closest examination fails to show any formation of oxide. Again, the frothing is greater from the long end than from the short end of the piece of wire, whereas, if due to oxidation, it should be the same at both ends.

Now, the following facts make it certain that hydrogen is either the sole cause of the changes produced in iron by some acids, or is inseparably connected therewith:

1st. Only those acids which evolve hydrogen by their action on iron produce any change in iron and steel, nitric acid (which does not liberate hydrogen except under particular conditions) having no effect.

2d. It is difficult to collect the bubbles which form the froth on the moistened fracture of a piece of iron in sufficient quantity for analysis; but by putting a coil of wire, previously steeped in acid, into hot water under a bell-jar, the bubbles of gas evolved by the iron may be collected, and will be found to burn with the characteristic flame of hydrogen.

Hence it is probable that iron and steel, when placed in hydrochloric, sulphuric, or other acid, absorb some of the nascent hydrogen generated by the action of the acid, thus forming what, for the lack of a better term, may be called an alloy* of iron and hydrogen. This alloy may be compared to that formed when zinc is amalgamated with mercury; and just as in process of time the mercury disconnects itself from the zinc, appearing in globules on its surface, so hydrogen gradually disengages itself from the iron—a movement which is greatly facilitated by heat, as is natural to expect.

The analogy may be carried still further; for as amalgamated zinc is made brittle in consequence of the pores or interestices between the molecules of the metal being filled up by mercury, motion of one molecule over another being then impeded, so in like manner iron becomes brittle when its pores are filled up by condensed hydrogen gas; and naturally, when the hydrogen or mercury is driven out of the molecular interspaces, movement of the molecules on one another is less impeded, and hence the former toughness or elasticity is restored.

Nor is amalgamated zinc the only analogous case; for the following remarkable experiment lends further probability to the theory, by showing how rapidly the absorption of zinc by iron may take place, attended with similar results, as regards increased brittleness, to those which accompany the absorption of hydrogen. It also shows how rapidly, by a slight change of temperature, zinc may be disengaged from the iron, thereby causing it to regain its former toughness.

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* By the term alloy I mean a solution of one metal in another.

A piece of galvanized iron wire, of good quality, such that when cold it could be bent several times on itself and back again before breaking, was raised to a red heat so quickly that the coating of zinc was melted and only a small portion vaporized. On attempting to bend it while still red-hot, it broke off sharp, offering very little resistance to fracture. The fracture was of a uniform blue-grey color, as though the zinc had penetrated into the interior of the iron. When cold, the same piece broke with all its former toughness and with a long fibrous fracture. The wire was again heated till the coating of zinc was completely vaporized, and then it was found to be so tough that it was impossible to break at a red heat. Wire in red-hot molten zinc will often break short, though the part out of the metal remains quite tough.

It is remarkable that this experiment will not succeed with all kinds of iron, some not being made thus "red-short" by zinc.

By way of testing the theory that occluded hydrogen is the cause of the change in the properties of iron after its immersion in acids, the writer determined to dispense with acid altogether, and endeavor to produce the same result by subjecting pieces of iron to the action of nascent hydrogen.

"With this view two pieces of iron wire .07 inch diameter were connected respectively with the zinc and copper plates of a battery of 80 Daniell's cells, and immersed in a vessel of Manchester town's water at a distance of 1 inch apart. On closing the current, bubbles of hydrogen were given off from the wire connected with the zinc plate of the battery, but none from the wire connected with the copper plate, the oxygen liberated there apparently forming oxide of iron, which in 12 hours formed a muddy deposit at the bottom of the vessel. After 24 hours the surface of the wire connected with the zinc plate was unchanged; but on moistening the fracture bubbles were given off, just as if it had been immersed in acid. The other wire, though much oxydized and eaten away, did not give off bubbles when broken, and had not become brittle.

"A variety of experiments made in the same way with pieces of wire varying from 3 to 20 inches long, and immersed 5 to 24 hours in water, yielded similar results. It was found, however, that when the wire connected with the zinc plate was of steel, no bubbles were visible to the naked eye on wetting the fracture with the tongue, precisely as in the case of steel after immersion in acid. Twenty-four hours in a warm room restored the iron to its original state, and no bubbles were then seen on breaking and moistening the fracture.

"The water in the last experiments was then replaced by an aqueous solution of caustic soda, when, after two hours, the moistened fracture of the wire connected with the zinc pole of the battery was found to bubble. Twenty-two hours' longer immersion, the battery working all the time, caused the bubbles to be more abundant; the toughness of the wire was also diminished and its surface blackened. The wire at the positive pole was, however, unchanged, either on the surface or in toughness."*

From this we see that not only is acid not indispensable for the production of, at all events, the major portion of these changes in iron, but the latter can be equally well produced in an alkaline solution.

The apparatus remaining unchanged, the soda was next replaced by hydrochloric acid, 1.20 sp. gr. On then immersing the iron-wire electrodes for only 2 or 3 seconds, the negative electrode, where hydrogen was given off, was found to froth freely when the fractured extremity was wetted, as much, in fact, as after 15 minutes' immersion when the current was broken. Half an hour's immersion failed to produce any similar change on the positive electrode where no hydrogen was liberated. The absence of effect on the positive electrode is all the more remarkable, as a piece of wire of exactly the same quality, and immersed an equal time in the same liquid, but unconnected with the battery, had become brittle and frothed when broken. It thus appears that neither oxygen nor chlorine are, under these conditions, occluded by iron, or if occluded, that they produce no sensible change in its physical properties.

Nascent hydrogen having been shown to produce these effects, a trial was next

* Proc. Lit. and Phil. Soc. Manch. 1874, p. 130.

made to ascertain if any similar change could be produced in iron by leaving it in an atmosphere of hydrogen gas. With this object a glass tube $\frac{1}{2}''$ in diameter was filled with pieces of bright iron wire $\frac{1}{10}''$ in diameter, and a current of hydrogen passed through for periods of 1, 2 and 8 hours respectively, but without any perceptible change in the wire. The wires were then placed in a bottle three-fourths full of water, and hydrogen made to bubble violently through the water for an hour, but still without any effect. It would thus appear that hydrogen is only occluded in the nascent state by iron in the cold. Possibly, however, absorption may take place if the surfaces are chemically clean. The late Dr. Graham, in his valuable papers on the occlusion of hydrogen, showed, several years ago, that when red-hot iron, palladium, or platinum are allowed to cool in an atmosphere of hydrogen, this gas is occluded by them in large quantity; and in the "Proceedings of the Royal Society," 1868, xvi. p. 422, he mentions that the best way of charging any of these metals with hydrogen is to make the metal act as the negative electrode in acidulated water for a battery of 6 Bunsen's cells—a fact unknown to the writer when he made experiments.

Though the absorption of hydrogen by iron is no doubt the cause of the frothing and diminution of toughness attendant on the immersion of iron in hydrochloric and sulphuric acids, there are some phenomena which cannot be explained by it alone, but which seem to show that the occlusion of hydrogen is accompanied by the absorption of a minute portion of the acid by the pores of the iron.

In proof of this the following well-established facts are adduced :

1st. Iron much sooner regains its natural state after immersion in hydrochloric than in sulphuric acid, though at first both may have equally affected it, as judged by diminution of toughness. It may be thought that some portion of the less volatile sulphuric acid adhering to the surface of the iron, even after prolonged washing, will account for it. This cannot be the case however; for the wire may not only be repeatedly washed in water, but even coated with lime-water, dried, and finally reduced in diameter two thirds by drawing several times through a steel die, processes which must surely remove any surface-coating of acid ; and yet it will take longer to recover its original toughness if cleaned in sulphuric acid than in hydrochloric acid.

2d. The pieces in the last experiment immersed in hydrochloric acid will become spotted with rust on the surface some days before those immersed in sulphuric acid.

If the supposition that acid is absorbed by the iron be correct, this is only what we should expect; for it is only natural to suppose that the most volatile acid, viz. hydrochloric, will come to the surface first.

We know, moreover, that water can by great pressure be forced through considerable thicknesses of cast iron. Why, then, should not a liquid pass into the pores of wrought iron?

As further proof of the presence of acid in iron, I have found that blue litmus-paper was slightly reddened when moistened by a drop of water which had been carefully placed on the fracture of a piece of iron 45″ in diameter, previously immersed in sulphuric acid several hours, and then washed in water. The drop of water in this case did not moisten the sides of the fracture, where some trace of acid might be present.

The occlusion of hydrogen by iron when immersed in acid solutions enables us satisfactorily to account for some of the difficulties experienced in depositing copper, silver, tin, or other metals from their solutions in acid in electrotyping or otherwise. Generally any coat of appreciable thickness slowly shells off, leaving the surface of the iron bare in places, and so making the coat of no avail as a preventive of oxidation. The case is obvious; the hydrogen occluded whilst the iron is being cleaned in a bath of vitriol or hydrochloric acid, and subsequently imprisoned by the coat of metal, must escape, and in so doing forces its way out, loosening or carrying away some portion of the superficial covering of the metal. If, however, the iron, after being cleaned in acid, is boiled in caustic-soda solution, a process which effectually expels the occluded hydrogen, a coating of copper or other metal may then be electrically deposited which will not shell off in the least. This is actually being done in practice; and large numbers of iron articles are now coated with a covering of copper four-thousandths of an inch in thickness.

In connection with this subject, I wish to refute a statement made by Professor Reynolds, in a paper read before the Lit. and Phil. Society of Manchester, Feb. 24th, 1874, an abstract of which appeared in the "Journal of the Chemical Society," June, 1874, p. 546, and other journals. The Professor states that I did not attribute the frothing of iron after immersion in acid to the escape of hydrogen, but to the action of acid. In my first paper on this subject (Proc. Lit. and Phil. Soc. Manchester, p. 80, 1873) the following passage occurs: "It seems probable that a part of the hydrogen produced by the action of the acid on the iron may be absorbed by the iron, its nascent state facilitating this. And when the iron is heated, by the effort of breaking it, the gas may bubble up through the moisture on the fracture." This shows that in my first paper I comprehended the true nature of the phenomenon.

Change produced in the breaking-strain and ultimate elongation of iron and steel by hydrogen occluded in it after immersion in hydrochloric and sulphuric acids.

In the earlier part of this paper some few of the changes in the properties of iron produced by occluded hydrogen have been examined. The degree of this change it has not always been possible to determine. In the case of the diminution of toughness, for example, no exact and easily applied test has yet been devised by which we can obtain with precision a numerical result expressing the relative toughness of any two examples; consequently we must be content with less definite results. This difficulty is fortunately not met with in the examination of the change in elasticity and tensile strength; for the breaking-weight and maximum elongation of any number of samples can be pretty easily ascertained, with great accuracy, and numerically expressed, thus making comparison easy.

Bearing in mind the numerous uses of iron and steel, and the probability that at times hydrogen may be occluded in them, altering their strength in a way little anticipated, it seemed of some importance to determine these changes —and the more so, as any experiments of this kind could not fail to throw some light on the molecular arrangement of metal in different qualities of iron and steel, a subject in itself of much interest. With this object upwards of 350 experiments have been made at various times with a very accurate machine, by which any weight could be brought to bear on the wire to be tested without the least jar—a very important point, though difficult of attainment, in experiments on tensile strength. The elongation at any moment could also be easily read off. The length of the pieces tested was in all cases the same, viz. 10 inches between the dies, and the temperature at the time of experiment about 16° C. I mention these points, as any variation in the length or temperature of the pieces tested will alter the result considerably. In order also to obviate, as far as possible, errors arising from the irregularity and absence of perfect homogeneousness of structure, even in the most carefully prepared iron and steel, the number of tests has been multiplied as much as possible and the mean only given.

The mode of experiment was as follows: After immersion in acid, the pieces were wiped and then tested, this giving the tensile strain and elasticity when containing occluded hydrogen; subsequently they were heated on hot plates or in ovens, as the most ready method of expelling the hydrogen, to a temperature considerably below that required to anneal them; and when cold, the breaking-strain, etc., of the iron, which had now recovered its natural state, was again ascertained by testing.

It might be thought that tests of iron in its natural state could be best made by experimenting on it before immersion in acid. Results so obtained cannot, however, be fairly compared with tests of the same piece made after immersion in acid, as the action of the acid somewhat reduces the diameter of the iron.

The following results are the means of 30 tests made on *annealed* and *bright* iron wire respectively—first, after being one hour in hydrochloric acid, and secondly, after being heated 12 to 48 hours to drive off the hydrogen.

	Breaking strain.	Mean error in breaking-strain.	Elongation.	Mean error in elongation.	Number of experiments of which each result is mean.
		per cent.	per cent.	per cent.	
Annealed iron wire when containing H.	100	±1.16	20.5	±1.12	12
Annealed iron wire, H expelled	100.487	±1.37	21.3	±1.71	12
Bright iron wire when containing H.	100	±2.57	2	±0.66	3
Bright iron wire, H expelled.	100.274	± .47	2.83	±0.64	3

Thus the tensile strain of *annealed* iron wire appears to be affected to twice the extent that *bright* wire is by immersion in acid for same length of time. The reverse is the effect on elongation.

Longer immersion in acid causes the iron to take up more hydrogen, and makes the change much greater, as the following experiments show. Denoting by 100 the breaking-strain of *bright* charcoal-iron wire after 12 hours' immersion in very dilute sulphuric or hydrochloric acid, and subsequent 5 hours' exposure in air at a temperature of 12°, during which time some of the occluded hydrogen must have escaped, then the breaking-strain of the same, after being 5 days on a hot plate to expel the dydrogen, is as follows:

	Breaking-strain.	Mean error in breaking-strain.	Elongation of length tested.	Mean error in elongation.	Number of experiments for each result given.
		per cent.	per cent.	per cent.	
Charcoal-iron wire containing H occluded in H^2SO^4	100	±1.33	1.3	±0.23	6
Charcoal-iron wire, H expelled by heat.	106.62	±7.10	4	±0.33	6
Charcoal-iron wire containing H occluded in H Cl.	100	±0.3	1.41	±0.41	6
Charcoal-iron wire, H expelled by heat.	105.35	±1.1	4.6	±0.33	6

The diminution of elongation and breaking-strain caused by occlusion of hydrogen is very marked in these experiments, but is quite equalled by the following experiments on mild steel containing about 0.227 per cent. carbon. The wires were allowed to remain in very dilute hydrochloric acid about 5 hours, then, when tested, heated to about 100° C. for 12 hours, by which means a portion of the occluded H was expelled.

	Breaking-strain.	Mean error in breaking-strain.	Elongation.	Mean error in elongation.	Number of experiments for each result given.
		per cent.	per cent.	per cent.	
Annealed mild steel containing H	100	± 5.08	20.1	±0.61	9
Annealed mild steel, H partially expelled by heat	104.77	± 3.81	15.4	±1.2	9
Bright mild steel before immersion in H Cl	104.03	±10.1	1.66	±0.44	6
Bright mild steel containing H	100	± 9.2	2.8	±0.46	6
Bright mild steel H partially expelled by heating twelve hours	108.68	± 1.5	2.16	±0.38	6
Bright mild steel, H completely expelled by heating seven days	114.29	± 8.4	3.42	±0.75	6

These experiments show:

1st. That the tensile strain of steel is diminished by the occlusion of hydrogen, and that as the hydrogen is expelled (a process of long duration) the tensile strain rises, till eventually it exceeds the original strain before immersion in acid.

2d. A most unexpected change in the elasticity of steel, the elasticity of the wire being considerably increased by the occlusion of hydrogen; but when a portion of this hydrogen is expelled by heat, the elasticity, as measured by elongation at the moment of fracture, falls remarkably, as much as 4.7 per cent. in annealed and 0.64 per cent. in bright steel. When the hydrogen is completely expelled, the elasticity, however, rises, being then greater than before immersion in acid.

The following experiments on hardened and tempered cast-steel wire containing about three times as much carbon as the mild steel, show an extraordinary diminution of the tensile strain when containimg occluded hydrogen; this, however, is regained or even surpassed when the hydrogen is expelled by heat.

	Breaking-strain.	Mean error in breaking-strain.	Elongation.	Mean error in elongation.	Number of experiments for each result given.
		per cent.	per cent.	per cent.	
Steel before immersion in acid	123.79	±2.7	2.16	±0.27	6
Steel immersed in $H^2 SO^4$ 12 hours	100	±4.9	1.916	±0.416	6
Steel, H expelled by heating 10 days to from 100° to 200°	122.53	±6.09	2.66	±0.55	6
Steel before immersion in $H^2 SO^4$	100.27	±1.28	3.75	±0.25	2
Steel after immersion in $H^2 SO^4$ 1 hour	100	±2.19	3.75	±0.25	2
Steel heated 24 hours to 100°–200°, to expel H	105.49	±2.9	2.75	±0.25	2

The change produced by occluded hydrogen must have an important influence on the stability of all iron and steel structures; for as the rusting of iron is mainly attributable to the action of the carbonic acid in the air, it is probable that the hydrogen liberated when the acid attacks the metal is occluded by the iron or steel, with consequent diminution of tensile strength and elasticity. In some cases, where rust has spread very rapidly, the writer has noticed a decided diminution of toughness; but, as a rule, it is difficult to detect any change, as probably the hydrogen is present in very small quantity; also when it has reached a certain per centage its tendency to escape from the metal will balance the force of occlusion.

Electric Conductivity.

Several experiments have been made to ascertain if there is any alteration in the electric conductivity of iron wire when containing hydrogen.

Professor Stewart kindly allowed me the use of the Owens College apparatus, with which some of the following results were obtained:

Resistance of 6 feet bright charcoal-iron wire=100	100
Resistance of 6 feet bright charcoal-iron wire after 5 hours in dilute H^2SO^4= 107.14, or, allowing for iron eaten away by acid	105.6
Resistance of 6 feet bright charcoal-iron wire after 5 hours in dilute H Cl= 114.3, or allowing for iron eaten away by acid	109.4

The wires were somewhat eaten away by the acid, so allowance had to be made for the increased resistance due to decreased sectional area; this is made in the column to the right.

About 50 feet of hard bright iron wire, after 24 hours immersion in dilute sulphuric acid, gave a resistance of 2.94 ohms, and 2.92 ohms after the occluded hydrogen had been expelled by heat.

The above results, though far from uniform, are sufficient to show that there is an increase in the resistance of iron wire when it contains occluded hydrogen. I hope soon to make further experiments on this subject. It is worthy of remark that Professor Graham found the resistance of palladium containing occluded hydrogen was increased about 25 per cent. He also discovered that a palladium wire first elongated when charged with hydrogen, and then contracted when the hydrogen was withdrawn to less than its original length. The writer has detected a very small and similar change in the length of annealed iron wire under like condition, but has not yet observed in it bright iron wire, though he does not despair of doing so.

Diffusion of Hydrogen.

A number of experiments were made by allowing one-half of a piece of bright iron or steel wire to be acted on by dilute acid, and thus to occlude hydrogen while the other half was protected from this action, with a view of ascertaining if the occluded hydrogen could spread along the interior of the iron. Great difference was observed in the behavior of iron and steel; the fibrous structure of iron wire allows the hydrogen occluded in the part acted on by acid to spread into the other part, distinct traces of hydrogen being observed 17 centims. from the part affected by acid. The close unfibrous structure of steel, on the contrary, seems to oppose this altogether, it being questionable if the hydrogen spreads 2 to 3 centims. beyond the part immersed in acid.

When that part of the iron wire which was protected from but still affected by the acid was broken and the fracture moistened, the bubbles of gas arose almost exclusively from the centre of the fracture, while from the part immersed in acid they arose equally from the whole surface, and took less time to attain their maximum.

HEAVY ARILLERY.

From "Engineering."

All those interested in the improvement and perfection of our heavy guns —and upon their superiority over those of other nations, the military and naval power of England, almost wholly depends—will have read the report of the debate on the Woolwich system of rifling ordnance, which took place in the House of Commons. Captain Price, Captain Nolan, and Lord Elcho did good service in calling attention to the unsatisfactory practice that rules at Woolwich, and the efforts made by Lord Eustace Cecil and Mr. Hardy to defend the existing system failed entirely in their purpose. We hope and believe that the time is at hand, if it be not already come, when the barriers erected by official routine and prejudice shall be broken down, and the all-important questions of rifling and muzzle *v.* breechloading shall be reconsidered by the light of recent experience. If this be done fairly and thoroughly we believe that the Woolwich rifling, and all its grave errors, shall be swept away, and muzzle give place to breechloading, at all events for heavy guns.

It will be useful to investigate the reasons which induce us to advance this opinion, so entirely in opposition to the conclusions arrived at long ago by Select Committees, pertinaciously defended from all attacks by the War Office, and carried out without deviation at Woolwich.

And first as regards the present system of rifling. This was adopted at a time when there was very little experience on the subject, and nearly all that was really valuable had been derived from the practice obtained with the various experimental systems of Sir William Armstrong, and all of which were successively abandoned. Even so late as 1865, the shunt system, which has proved totally unsatisfactory for heavy guns, was warmly commended in a report by a special committee in the following terms: "If the so-called French system should fail in larger calibres than 9 in., the natural course would be to fall back on Sir William Armstrong's, which holds the second place; which has been more thoroughly studied and worked out than any other, and through a wider range of calibres, which is actually in the service of the muzzle-loading 64-pounder guns, and to which so many of our large experimental guns of large calibre—the 600-pounder, the 300-pounder, the 9.22 in., or 220-pounder—are conformed. To throw away the experience gained with these guns, and the expense incurred in the preparation of patterns and means of manufacture, without good cause, would be to postpone unnecessarily the adoption of a fixed system, and plunge anew into tedious and costly experiments on a mere hypothesis of improvements." Not long after this report the shunt system was abandoned for the larger calibres, but tedious and costly experiments were continued, and in 1870 it was finally given up for the lighter guns.

The number of grooves in the so-called Woolwich system varies from 4 to 9, with an increasing twist varying from nothing, or 1 in 100 to 1 in 35 or 40, and the projectiles as is well known are formed with circular recesses at suitable intervals, into which gun-metal studs are forced, these studs bearing against the grooves which thus gives rotation to the projectile. As the latter lies in the gun before being discharged, it is obvious that it must be out of centre, that is, that the axis of the shot is below the axis of the gun, so that nearly all the windage is at the top, while the projectile itself bears upon two points only where the studs rest upon the groove. This position of the shot with reference to the bore of the gun renders it liable, when the force of the powder gases exert themselves, to assume an oblique direction, and throw an undue strain upon the grooves, which makes itself evident in distorted and sheared studs, and later in scored and broken A tubes, while, of course, the whole of the work required to produce this destruction, is taken out of the useful work of the powder. To this cause must be assigned the great irregularities in the powder pressures ranging from 20 to 44 tons, which are from time to time recorded, and to account for which many ingenious theories were devised by the partisans of the system. In addition to the injurious effect produced by the studs upon the grooves, the studs themselves are an inherent source of weakness to the projectile, and account for many of the not unfrequent cases of breaking of shot and shell in the gun itself. It is a hard matter to break up a Palliser shell with a sledge hammer, unless a stud is struck, when "it may be surprisingly easily divided into two by a blow on the stud fixed on the present system. If shot are found split in store, the crack generally runs through stud holes." With regard to the increasing twist, the principal if not the only reason for its adoption, is that a considerable strain is thrown upon the gun if it is suddenly called upon to rotate a heavy shot, with the velocity due to the force of the explosion. This objection bears but little weight in fact, and what small reason there was in its favor has disappeared with the introduction of slow-burning powder. Varying twist in the service rifling involves the necessity of studs, and studs involves the rapid destruction of the A tube, and the occasional breaking up of the projectile in the gun. So active are these causes of injury that the actual weights of projectiles and powder charges used in the heavy calibres have been reduced and the utmost precautions are used in firing guns for practice lest they should become irretrievably damaged, as so many have been, yet with all the care that is taken the "cemetery of suicides" at Woolwich bears evidence to the fatal defects of the French rifling. And it is worth noticing that in almost every case, whether the damage done be ascribed to the bad steel of which the tube is made, to the ownership of the gun (as in the case of Major Palliser's 68-pounder converted gun), or to the breaking up of the shell, or to the fault in the fuse, or in fact to anything but the system, the connexion between cause and effect is never remote nor difficult to trace. But besides these drawbacks to the system, which we imagine no one will venture to deny, because they cannot be disproved, a lower initial velocity and less penetration, together with marked inaccuracy of short ranges, are characteristics of the Woolwich rifling. As an illustration, we may refer to the Glatton-Hotspur experiments which were made some time ago, and in which several rounds from the 25-ton 600-pounder were fired by the Hotspur, against the turret of the Glatton, protected with 15 in. armor and 14 in. backing. The range was only 200 yards, yet none of the seven shots fired struck the point for which the gun was laid ; thus the sixth which was the first effective shot, struck 18 in. below the bull's-eye

Now this defective practice was not the fault of the gunners, but was simply an instance of the well-known "inaccuracy of flight observed in the 12-in. 25-ton gun at short ranges," and this fact was pointed out by Captain Hood to the War Office some years before the Glatton-Hotspur experiment. Even so long ago as 1864, before the final adoption of the French rifling, it was shown "that this system has decidedly the lowest velocities." This was settled to the satisfaction of the select committee at the time, and it is marvelous how, in the face of such direct evidence, the present pernicious system has been maintained. To quote one experiment of that time will serve our purpose. Two $7\frac{1}{2}$-in. guns throwing 110-lb. shot, were fired under precisely similar conditions. The shot of one gun was rotated by means of studs, taking a bearing of less than 1-in. in each groove of an increasing twist, while the other had a rib bearing 9.2 in. long for each groove of a uniform spiral. There were 133 comparative rounds fired from each gun, and the result showed an average of 59 feet increased initial velocity for the ribs as compared with the studs, and—at an elevation of 2 deg.—as great a range with 20-lb. of powder for the former as with 25 lb. for the latter. Now as the conditions of firing were alike, it followed that the work due to the extra 5 lb. of powder had been absorbed, and examination showed that it had been divided between the projectile and the gun, the studs on the former having been distorted and sheared, while the grooves in the latter in doing this had become seriously injured, and the gun was effectually destroyed in 567 rounds. And the experience of the early history of Woolwich rifling is that of to-day, only with larger calibre and heavier charges the causes of destruction rapidly increased, far more rapidly than the improvement in material and construction has increased, and we have not in the service one gun of heavy calibre which can be relied upon, or which under the most favorable circumstances can be expected to last without relining more than 375 rounds, while the chances are that it may be disabled after the first few rounds.

The assurance of Lord Eustace Cecil that the subject is hardly ripe for discussion in the House of Commons, or that of Mr. Hardy, that the official eye will be kept upon the matter, will scarcely satisfy the country.

We come now to the second part of this important question—muzzle *v.* breechloading. We are the only muzzle-loading nation, for the United States has no artillery, only big guns. France and Germany, Russia, Austria, Italy, Turkey and Sweden, great powers and small, have adopted a breechloading ordnance.

With the exception of France and Sweden, all the important Continental nations employ the same system—the Broadwell sliding block. France and Sweden with their cast-iron reinforced guns have preferred another and far less perfect method. So far as this country is concerned, our experience has practically been limited to the Armstrong arrangements, imperfect and complicated for small calibres, impracticable for large ones, and now definitely abandoned in the service. But it is idle to argue that because we have failed, and because powerful partisans of muzzle-loading have persistently declared themselves against breechloading, that the latter is inferior. The fact that all Continental nations have adopted it is a sufficient reply, for artillery officers and scientists abroad have applied themselves with as much earnestness to the solution of the problem and with less prejudice as has our own War Office. Among the chief advantages which breechloading possesses, as compared with muzzle-loading, are the perfect fitting of the projectile in the bore, the true centring of the shot, the quicker and more convenient serving of the gun, and the greater security to the gunners, and as the consequence of these advantages follows in combination with a suitable class of rifling with uniform twist, far greater endurance of the gun, higher initial velocity of the projectile, increased accuracy, and better powers of penetration.

We have already in these columns described and illustrated the beautiful system perfected by Mr. Broadwell, but we may here briefly notice its principal features.

In these guns the breech extends beyond the shot and powder chamber, and a large slot is formed in it at right angles to the axis of the bore. In this slot slides a so-called cylindro-prismatic block, which can be withdrawn in order that the charge may be introduced into the chamber. Around the base of this chamber is a hemispherical socket, in which is placed a ring, the front edges of which are turned down thin, in order that they may freely expand against the socket when the force of the explosion takes place. The back of the ring is flat, and has formed in it several small concentric grooves for the reception of dust and grains of unburnt powder which may accumulate. In the face of the breech block is a circular recess, the diameter of which corresponds with the outside diameter of the ring. In this recess is placed a steel plate, and against this the ring takes its bearing. The cylindro-prismatic block is moved to and fro by means of two screws. The first of these is a quick motion screw with several threads upon it. This screw is merely used for running the block easily in and out, and is dispensed with in all calibres less than 8 in. In these smaller natures handles are attached to the end of the block, which is moved by hand. The second screw is employed for jamming and locking the block, and it works into a large cylindrical nut let into a socket made in the broad end of the large block. A portion of the thread of this screw is cut away, so that as it is turned the thread may either engage or disengage with the breech of the gun, and the block is thus locked or unlocked. As the block is run home (and this can be done easily without the screws, and by one hand even in the 12-in. gun), the circular plate and the back of the ring come into close contact, and from their form it is impossible that either can be displaced. It will be seen from this description that there are only two pieces of this sytem exposed to destructive action, the ring and plate, and these can if necessary be easily and quickly replaced, and at a very small expense. Experience, however, has shown that such a contingency very rarely occurs, and both ring and plate as a rule will last as long as the gun itself.

Such is the device perfected by Mr. Broadwell, a device copied by Krupp in every detail, and adopted by him in every gun large and small which he manufactures, and which has withstood satisfactorily every test, both in the field and the test ground. When Mr. Hardy stated the other evening in the House of Commons, that in the case of breechloaders, accidents were constantly happening from the breech being carelessly or hastily closed, and when Lord Eustace Cecil said that he had found, on inquiry, that from the year 1863 down to the present time serious accidents had occurred in the use of Krupp guns, each showed either an ignorance of actual fact or a desire to throw discredit on breechloading. It is quite true that for some years after 1863 serious accidents did happen with the Krupp gun, but these were with the old imperfect systems then in use, the Wharendorff, Kreiner and Krupp, where papier maché cups were attached to the rear of the cartridges, and the whole device was crude.

But since the existing European system of breechloading—that is to say, the cylindro-prismatic breech-block and ring of Broadwell—has been adopted, no accidents arising from the mechanism are recorded, although Krupp guns have doubtless been destroyed and disabled through faulty material. For full particulars of this question, as well as of the important part Mr. Broadwell has taken in giving to the world a thoroughly efficient breechloading gun, we refer our readers to the second part of the Reports upon the Vienna Universal Exhibition, pages 837 *et seq.*

We may fairly claim to have the most perfect appliances for the manufacture of heavy guns in the world, we may claim also a high superiority in materials and workmanship, as well as in the form and distribution of those materials, but we must admit, and we believe that all but those determined to uphold, at any cost, a faulty system, rather than abandon pet theories, will admit also, that our superior workmanship, material, and mode of construction are combined with serious if not fatal defects.

Durability, accuracy, and power of penetration are the essential qualities of heavy ordnance, and these we can never obtain, while a large percentage of the powder charges are employed in destroying both gun and projectile, when the bearing of the latter in the grooves is quite insignificant, and its position with relation to the bore, encourages or rather enforces the "oblique movement of the axis," imparted to it when it is put in motion, and which it carries with it in its flight.

STEEL BRONZE.

From "The Engineer."

Austria is dissatisfied with her field guns. For some time, and especially since the Franco-German war, the Austrian authorities have been engaged in experiments and trials for the improvements of their artillery, and many partial accounts of their work have reached our ears. The idea of compressing steel when in a state of fusion, conceived and carried out by Sir Joseph Whitworth, led to many experiments in the same direction; and about two years ago the Archduke Guillaume, Director-General of the Austrian artillery, brought from Russia a specimen of bronze which had been compressed when in a fluid state, and which was found greatly superior to the bronze in use in Austria. About the same time M. Lavessière, of Paris, exhibited at Vienna bronze and bronze guns of the same quality. These circumstances led Colonel Uchatius, director of the arsenal at Vienna, whose name is attached to a peculiarly fine and tenacious kind of steel made in Sweden, to take up the subject in an exhaustive manner, and the results are now before us.

Colonel Uchatius found that with an alloy of 90 per cent. copper and 10 per cent. of tin, and a pressure of about eighty tons, he could produce bronze equal in hardness to the Russian specimen. A cast iron mould 0.26 metre in diameter and 0.70 metre high, was thus filled with liquid bronze, which solidified in five minutes, and contracted so powerfully in the direction of the axis that the only part of the ingot which could be considered as sound was that which filled the lower part of the mould to the height of about 0.18 metre. In breaking this cylindrical mass the outer portion was found to be of a crystalline texture, of golden color, gradually changing to a dense grey mass in the centre. But bronze thus cast was still wanting in the qualities required for guns. The metal was very tenacious, and the cannon rarely burst, but the elasticity of such metal is not much greater than that of ordinary bronze, and it is not hard enough to rifle the copper bands of projectiles. Colonel Uchatius then tried the experiment of cold rolling bronze cast in an ingot, and succeeded in increasing its power of resistance, elasticity, and hardness. He found that the metal could be rolled out to double its original length without the slightest trace of cracking, and that when elongated only 20 per cent. the bronze acquired the hardness, the elasticity, and the resistance of steel. Experiments also proved that the elasticity of all tenacious substances increased rapidly when they were subjected to a force which exceeded the limit of the elasticity, a fact which Colonel Uchatius considers of considerable importance in metallurgical industry. Thus bronze cast in an open cylindrical mould attains the limit of its elasticity under a force of 400 kilogrammes, which corresponds with an elongation of the original length by about $\frac{4}{10000}$ parts, whereas if it be subjected to a tensile force which lengthens it permanently $\frac{4}{1000}$, the limit of its elasticity is raised to 1,600 kilogrammes, with an elastic increase of $\frac{192}{100000}$ of the primitive length. Colonel Uchatius thus sets down the conditions which are to be realized in the manufacture of bronze cannon: The effect of the explosion of the powder in the breech of the arm should be counteracted by a mechanical compression of the metal of the interior to a degree greater than that caused by the explosion of the charge; the metal employed for the interior of cannon should therefore be submitted to a treatment analogous to rolling, which at the same time will give the metal the desired degree of hardness. The questions remain: Which is the best kind of bronze? and, can a metal be obtained which is perfectly homogeneous in quality from the circumference to the centre?

To settle this point seven alloys were tried.

Number.	Tin.	Copper.	Zinc.
1	12 per cent.	88 per cent.	Nil.
2	10 "	90 "	"
3	8 "	92 "	"
4	6 "	94 "	"
5	10 "	88 "	2 per cent.
6	10 "	89 "	1 "
7	8½ "	91 "	½ "

The last is the alloy used by M. Lavessière. Two small bars were cut out of each ingot, and were rolled until they had acquired the hardness of steel. No. 1, however, would not roll. Nos. 2, 3 and 4 rolled well; the zinc in the three last examples was found of no appreciable utility. Nos. 2, 3 and 4 were subjected to strains of 5,066, 5,200 and 5,460 kilogrammes respectively. The limits of their elasticity were found to range from 1,700 to 1,300 kilogrammes, and the permanent elongation to arrive at the desired hardness was in the case of No. 2, 20; in that of No. 3, 30; and of No. 4, 50 per cent.

The only mode apparent for producing homogeneousness throughout the ingot was to cool at once the inside and the out, by the adoption of a double mould. A bronze tube was therefore introduced into the mould, and a stream of water kept up through the tube during the running. The whole mass was found to be crystalline, but there were flaws in concentric circles around the core. Air was tried instead of water, but in that case the bronze tube melted ; solid cores in bronze, copper and cast iron were tried, and a solid forged copper core 0.05 metre in diameter gave satisfactory results. The bronze cylinders thus obtained were 0.62 metre in diameter, and 0.30 metre long; they were turned down to 0.18 metre outside, and the interior bored out to 0.08 metre. The cylinder was then opened by means of conical steel drifts and a hydraulic press ; six drifts were employed, the first being 0.002 metre larger in diameter than the interior of the bronze cylinder, and the last only 0.0005 metre larger than the fifth, so that the cylinder was enlarged 2 per cent.; the interior was then excessively hard and polished, and was ready for rifling. A pecular advantage claimed for this mode of compression is that if the metal were not sound the fault would immediately appear ; and it is remarked that after the last drift has been withdrawn the bronze cylinder contracts again to the extent of $\frac{4}{1000}$, which proves that the different parts had undergone compression equal, according to calculation, to a central radial pressure of 2,400 atmospheres. The alloy No. 3, containing 8 per cent. of tin, was found, after many trials to be the best, and the most economical. The qualities of these bronze guns are summed up in the following terms :

The cannon produced in the manner described are declared to possess all the hardness, homogeneousness, and resistance of steel tubes. The quality of the bronze varies from the exterior to the interior of the piece in proportion to the force to be resisted ; the hardness, elasticity, and solidity diminishing from the interior to the outside, and all these qualities are more developed than in steel guns. The elasticity of which the direction is opposed to that of the explosive force of the charge, acts in a continuous manner from the exterior surface of these bronze guns to the interior ; but the neutral axis, where the interior and exterior forces are in equilibrium, is very near to the inner surface. For such a gun to burst the elasticity of the whole mass must be overcome simultaneously, and the great tenacity of the external part, which will bear an extension of 70 per cent. without rupture, is opposed to the action of the explosive force. In the guns formed with rings sunk on the neutral axis lies between the central tube and the strengthening rings, the consequence of which is that the latter have to support the whole force of the explosion. With respect to the wear of the interior surface of the chambers of the guns, Colonel Uchatius says that chemical action plays no part in it, and that it is due merely to the violent projection of the grains of powder which act like sand upon the metal, and that the effect is always most apparent where the metal is the hardest, which explains the necessity of placing a copper tube in the touchhole. The compressed bronze is not more liable to wear than steel. This bronze is much less affected by atmospheric agency than steel. The cost of bronze guns is much less than that of steel, if the value of the old metal be taken into account.

Finally, the new bronze is declared to surpass all materials yet applied to the production of guns, and if the trials which are about to be made with a large number of field pieces should corroborate the experiments made on a small scale, the production of steel guns will be abandoned. One of these new bronze guns has borne several hundred discharges, with the ordinary charge, successively, without the slightest deformity or injury being apparent in any part of the piece.

EUROPEAN LIGHTHOUSES.*

From "Engineering."

As a rule United States Government reports belong to one of the two extreme classes, they are prepared either extremely well or extremely ill. Unlike our own official reports they lack the sameness of appearance imparted by the blue uniform which has given to this class of literature in our country its generic name. The extent, completeness, value, and elegance of the American official report, depends, to a large extent, upon the judgment, capacity, and taste of its author, these being subject, it need scarcely be said, to the sum of money placed at his disposal for the purpose.

The report we take up for review on this occasion belongs, we are glad to say, to the former of the two extremes mentioned above ; its subject is a rich one, and Major Elliott has made the most of the advantages he possessed in its preparation. We regret to notice on the title page that only one thousand copies were printed, these being for the use of the Treasury Department, so that unless it be republished, in unofficial form, its value must be greatly reduced by its scarcity. For this reason, therefore, we propose to review the work with some fullness, and with the care it merits.

The object of the work is clearly explained in the following extract from the Report of the Lighthouse Board to the Secretary of the Treasury for the fiscal year ending June 30th, 1873 :

"The Lighthouse Board during the past year, desirous of acquainting itself minutely with any improvements which of late years may have been introduced into the lighthouse services in Europe, obtained the sanction of the Honorable the Secretary of the Treasury to commission Major Elliott of the corps of engineers of the army, and engineer secretary of the Board, to visit Europe and report upon everything, which he might observe relative to lighthouse apparatus and the management of lighthouse systems."

Major Elliott left New York in the steamship Cuba, in April, 1873, and he prefaces his report with various items of information obtained from the commander of that ship upon the relative efficiency of the lights and systems on the American and European coasts. From this it appears that the English and American lights are about equal in brilliancy, but that the French ones are superior to either. Both English and French electric lights have a far greater power of penetrating fog than the common oil lights. The American fog signals are deserving of high commendation, especially the steam whistle at Cape Ann and the siren at Sandy Hook, which may be confidently relied upon at six or eight miles distant. Upon arriving in England, Major Elliott was received at the Trinity House, and arrangements were made to give him every facility for pursuing his investigations, and obtaining all the information he desired. It was just at this time that the series of exhaustive experiments upon the transmission of sound signals was about to be commenced by the Trinity House, under the supervision of Professor Tyndall, and the author devotes considerable space to the description of these interesting and valuable trials, indeed he reproduces Professor Tyndall's final report to the Trinity House upon the subject. In the course of these experiments two sets of signals were used, one placed on the summit of the cliff near the engine-house belonging to the light station, and 275 feet above the sea ; the other near the foot of the cliff, at a height of 40 feet above the sea. Three classes of instruments were used — steam-whistles, air-whistles and fog-trumpets. The trumpets and air-whistles were connected with air chambers, supplied by the engine pump. The steam whistles were supplied from a 20 horse-power boiler (not engine, we presume, as Major Elliott says). These whistles were 12 in. in diameter, and 14 in. high, the space

* Report of a Tour of Inspection of European Lighthouses, made in 1873 by Major George Elliott, Member and Engineer Secretary of the Lighthouse Board, under the authority of the Honorable William A. Richardson, Secretary of the Treasury, Washington. Shortly to be published by D. Van Nostrand.

between the lip and the disc being $17\frac{1}{2}$ in. The air-whistles were 6 in. diameter, and $9\frac{1}{2}$ in. high, with $1\frac{1}{2}$ in. between the lips and discs. A pressure of 64 lbs. was used for the steam-whistles, and 18 lbs. for the air-whistles, behind which were placed reflectors 12 ft. by 15 ft. slightly curved. The facts it was desired to determine were chiefly: 1. The best height above the sea level for signals; 2. The comparative values of air and steam for signaling purposes; 3. Whether the whistle or horn is the most efficient; 4. The most effective pressures; 5. The relative advantages of long and short blasts; 6. The most efficient notes; 7. The relative ranges of the horn in the direction of its axis, and at 45 deg. and 90 deg. respectively from the direction of its axis; 8. Whether the horn is used with maximum efficiency by always keeping it pointed to windward, by using more than one horn and distributing the sound over the phonic arc, or by rotating one horn; 9. Whether reflectors are of value, and if so, to determine the best form; 10. What is the horse power required to give the most efficient signal for the steam as well as the air-whistles, through fog and against wind of a given force; 11. How the propagation of the sound is affected by different atmospheric conditions. How this programme was carried out is amply recorded in the report addressed by Professor Tyndall to the Trinity House.

After taking part in the preliminary experiments just referred to, Major Elliott proceeded to examine the South Foreland electric lights. These lights are placed about 1,000 ft. apart, one being 372 ft., and the other 275 ft. above the sea. The electric current for producing these lights is generated by four Alliance magneto-electric machines, each machine being composed of 96 helices, mounted upon six gun-metal wheels, each having 16 helices. Between these wheels are placed the magnets, eight in each division, 40 of them being composed of six plates rivetted together, and 16 of them having three plates. These magnates are fixed, while the helices are driven with a speed of 400 revolutions per minute. The total lifting power of the magnet is 5,184 lbs., and the engine required to drive the machine is of six horse power. Major Elliott gives some very good drawings, and a detailed description of the Alliance apparatus. The illuminating agent in the lamp at the South Foreland consists of two pieces of carbon, 10 in. long by $\frac{3}{8}$ in. square. They are made of coke dust, and their rate of consumption is 34 in. per night for each lamp, and the cost is one penny per inch. The power of the beams thus produced and condensed, is equal to 180,000 candles for each lamp.

Major Elliott next visited the Trinity House depot at Blackwall, and describes with much minuteness the organization and apparatus of that establishment, and this part of his report is of high interest. Traveling round the coast, the reporter inspected, and describes and illustrates the lighthouses at the mouth of the Thames, at Yarmouth, Haisborough, the Humber, Flamborough Head, Whitby, South Point, Coquet Island, the mouth of the Tweed. Coming back then to the south, he continued his work of inspection of the different lighthouses along the southern coast—St. Catherine's, Portland Hill, The Start, Eddystone, Plymouth, the Lizard, the Wolf, &c., and in each case he notes the salient points and distinguishing features of each, whether of construction, lighting, or management. In the same way Major Elliott deals with the lights around the Irish coast.

Passing over to France, Major Elliott arrived in Paris, and visited the Lighthouse Board of France. This board is composed of four engineers, two naval officers, one member of the Institute, one inspector-general of marine engineers, and one hydrographer. Here he had an opportunity of comparing the depot with its contents, organization and management, with that of England.

In a similar manner also he visited and carefully inspected the principal French lights, recording the various systems in use, and dwelling at considerable length upon the successful results with which mineral oil has been introduced for illuminating purposes. Did space permit, we would gladly follow Major Elliott through his careful examinations. We must content ourselves, however, by briefly noticing the conclusions at which he arrived, after his tour of inspection was completed.

According to the author, the marked

superiority of English and French lights over American is clearly established. The latter have but a fixed illuminating power for all weathers, equal to 210 candles, whilst the English oil lamps can be increased from a minimum of 342 to 722 candles.

He points out the advantages that result from the use of mineral as compared with vegetable or animal oil, that while the cost is a little more than one-third, it is more cleanly and regular, the lamps burning require to be trimmed less often, and therefore the brilliancy of the light is less dependent upon the watchfulness of the keeper.

He compares the organization and system of control in England and France with that of the United States, and indicates several ways in which by imitating the former, greater efficiency and economy could be secured for the latter He dwells upon the advisability of introducing the electric light into some of the more important light-houses in the United States, and instances the South Point light, which throws its concentrated beams over the North Sea with a power equal to 800,000 candles. He refers to the valuable facts established by Professor Tyndall for fixing the relative areas of the red and white panels of revolving lights, so that each color may be seen at equal distances—the ratio being as 21 to 9—and recommends that these proportions should be used in the United States, instead of panels of the same size. With several recommendations of minor importance, Major Elliott concludes a report full of valuable information to the Light-house Board, of which he is the engineer secretary, and at the same time full of interest to us, not only because he has indicated the exact conditions of light-houses and illumination in the United States, but because he has collected so large a mass of information about our own systems and lights. We can only repeat our regret that so small an edition of this admirably prepared and illustrated report has been printed, and that it is not offered for sale to the public.

ON THE DISSIPATION OF ENERGY.

By Lord RAYLEIGH, M.A. F.R.S. M.R.I.

Proceedings of the Royal Institution.

The second law of thermodynamics, and the theory of dissipation founded upon it, has been for some years a favorite subject with mathematical physicists, but has not hitherto received full recognition from engineers and chemists, nor from the scientific public. And yet the question under what circumstances it is possible to obtain work from heat is of the first importance. Merely to know that when work is done by means of heat, a so-called equivalent of heat disappears is a very small part of what it concerns us to recognize.

A heat engine is an apparatus capable of doing work by means of heat supplied to it at a high temperature and abstracted at a lower, and thermodynamics shows that the fraction of the heat supplied capable of conversion into work depends on the limits of temperature between which the machine operates. A non-condensing steam engine is not, properly speaking, a heat engine at all, inasmuch as it requires to be supplied with water as well as heat, but it may be treated correctly as a heat engine giving up heat at 212° Fahr. This is the lowest point of temperature. The higher is that at which the water boils in the boiler, perhaps 360° Fahr. The range of temperature available in a non-condensing steam engine is therefore small at best, and the importance of working at a high pressure is very apparent. In a condensing engine the heat may be delivered up at 80° Fahr.

It is a radical defect in the steam engine that the range of temperature between the furnace and the boiler is not utilized, and it is impossible to raise the temperature in the boiler to any great extent, in consequence of the tremendous pressure that would then be developed. There seems no escape from this difficulty but in the use of some other fluid, such as a hydrocarbon oil, of much higher boiling point. The engine would then consist of two parts—an oil engine taking in heat at a high temperature, and doing work by means of the fall of heat down to the point at which a steam engine becomes available, and secondly a steam engine receiving the heat given out by the oil engine and working down to the ordinary atmospheric temperature.

Heat engines may be worked backwards, so as by means of work to raise heat from a colder to a hotter body. This is the principle of the air or ether freezing machines now coming into extensive use. In this application a small quantity of work goes a long way, as the range of temperature through which the heat has to be raised is but small.

If the work required for the freezing machine is obtained from a steam engine, the final result of the operation is that a fall of heat in the prime mover is made to produce a rise of heat in the freezing machine, and the question arises whether this operation may be effected without the intervention of mechanical work. The problem here proposed is solved in Carré's freezing apparatus, described in most of the text-books on heat. There are two communicating vessels, A and B, which are used alternately as boiler and condenser. In the first part of the operation aqueous ammonia is heated in A, until the gas is driven off and condensed under considerable pressure in B, which is kept cool with water. Here we have a fall of heat, the absorption taking place at the high temperature and the emission at the lower. In the second part of the operation A is kept cool, and the water in it soon recovers its power of absorbing the ammonia gas, which rapidly distils over. The object to be cooled is placed in contact with B, and heat passes from the colder to the hotter body. Finally the apparatus is restored to its original condition, and therefore satisfies the definition of a heat engine. Mr. Carré has invented a continuously working machine on this principle, which is said to be very efficient.

Other freezing arrangements depending on solution or chemical action may be brought under the same principle, if the circle of operations be made complete.

When heat passes from a hotter to a colder body without producing work, or some equivalent effect such as raising other heat from a colder to a hotter body, energy is said to be dissipated, and an opportunity of doing work has been lost never to return. If on the other hand the fall of heat is fully utilized, there is no dissipation, as the original condition of things might be restored at pleasure; but in practice the full amount of work can never be obtained, in consequence of friction and the other imperfections of our machines.

The prevention of unnecessary dissipation is the guide to the economy of fuel in industrial operations. Of this a good example is afforded by the regenerating furnaces of Mr. Siemens, in which the burnt gases are passed through a passage stacked with fire-bricks, and are not allowed to escape until their temperature is reduced to a very moderate point. After a time the products of combustion are passed into another passage, and the unburnt gaseous fuel and air are introduced through that which has previously been heated. The efficiency of the arrangement depends in great degree on the fact that the cold fuel is brought first into contact with the colder parts of the flue, and does not take heat from the hotter parts until it has itself become hot. In this way the fall of heat is never great, and there is comparatively little dissipation.

The principal difficulty in economy of fuel arises from the fact that the whole fall of heat from the temperature of the furnace is seldom available for one purpose. Thus in the iron smelting furnaces heat below the temperature of melting iron is absolutely useless. But when the spent gases are used for raising steam, the same heat is used over again at another part of its fall. There is no reason why this process should not be carried further. All the heat discharged from non-condensing steam engines, which is more than nine-tenths of the whole, might be used for warming or drying, or other operations in which only low temperature heat is necessary.

The chemical bearings of the theory of dissipation are very important, but have not hitherto received much attention. A chemical transformation is impossible, if its occurrence would involve the opposite of dissipation (for which there is no convenient word); but it is not true, on the other hand, that a transformation which would involve dissipation must necessarily take place. Otherwise the existence of explosives like gunpowder would be impossible. It is often stated that the development of heat is the criterion of the possibility of a proposed transformation, though exceptions to this rule are extremely well known. It is sufficient to mention the solution of a salt in water. This operation involves dissipation, or it would not occur, and it is not difficult to see how work might have been obtained in the process. The water may be placed under a piston in a cylinder maintained at a rigorously constant temperature, and the piston slowly raised until all the water is evaporated, and its tension reduced to the point at which the salt would begin to absorb it at the temperature in question. After the salt and vapor are in contact the piston is made to descend until the solution is effected. In this process work is gained, since the pressure under the piston during the expansion is greater than at the corresponding stage of the contraction. If the salt is dissolved in the ordinary way energy is dissipated, an opportunity of doing work at the expense of low temperature heat has been missed and will not return.

The difficulty in applying thermodynamical principles to chemistry arises from the fact that chemical transformations cannot generally be supposed to take place in a reversible manner, even although unlimited time be allowed. Some progress has, however, recently been made, and the experiments of Debray on the influence of pressure on the evolution of carbonic anhydride from chalk throw considerable light on the matter. By properly accommodating the pressure and temperature, the constituents of chalk may be separated or recompounded without dissipation, or rather dissipation may theoretically be reduced without limit by making the operation slowly enough.

The possibility of chemical action must often depend on the density of the reacting substances. A mixture of oxygen and hydrogen in the proper proportions may be exploded by an electric spark at the atmospheric pressure, and energy will be dissipated. In this operation the spark itself need not be considered, as a given spark is capable of exploding any quantity of gas. Suppose, now, that previously to explosion the gas is expanded at constant temperature, and then after explosion brought back to the former volume. Since in the combination there is a condensation to two-thirds, the pressure required to compress the aqueous vapor is less than that exercised at the same volume by the uncombined gases, and accordingly work is gained on the whole. Hence the explosion in the expanded state involves less dissipation than in the condensed state, and the amount of the difference may be increased without limit by carrying the expansion far enough. It follows that beyond a certain point of rarity the explosion cannot be made, as it could not then involve any dissipation. But although the tendency to combine diminishes as the gas becomes rarer, the heat developed during the combination remains approximately constant.

It must be remembered that the heat of combination is generally developed at a high temperature, and that therefore work may be done during the cooling of the products of combustion. If, therefore, it is a necessity of the case that the act of combustion should take place at a high temperature, the possibility of explosion will cease at an earlier point of rarefaction than would otherwise have been the case.

It may probably be found that many mixtures which show no tendency to explode under ordinary conditions will become explosive when sufficiently condensed.

THE RAILWAYS AND RAIL TRADE OF THE FUTURE.

From "The Engineer."

It would be both superfluous and supererogatory to insist upon the vast importance of this wide subject to the industrial interests of the United Kingdom. To a great extent, indeed, it underlies all other considerations affecting our staple industry, and is synonymous with the progress of civilization itself. The question of what is to be the future of the railway system has recently been exercising the minds of all kinds and conditions of men. There are not a few who profess to regard railway development as having reached a deadlock, and who, therefore, promulgate alarmist theories about the industrial decay of Great Britain—the workshop as well as the parent of the railway system. Others, again, take a more optimist view of things, and with the "gay wisdom" for which Mr. Disraeli has panegyrized Sir Wilfrid Lawson, are ever declaring that henceforth, as heretofore, the progress of the world will be synchronous with the development of the railway system, and that, so far as Britain's industrial supremacy is concerned, to the extent that it is affected by the multiplication of railways, it will never pale until the vast continents of Asia and Africa have become as much interlaced with roads of iron as Europe and America. Collateral with this inquiry there is another of scarcely less importance to our industrial interests. Manufacturers of iron rails have within the last two or three years observed with feelings of considerable trepidation the growing preference for steel rails, and it has been more than hinted at that the iron rail trade is doomed to go to the wall. We shall here, therefore, consider (1) to what extent will the development of the railway system take place in the future; and (2) how far will that development affect the enormous capital invested in the production of iron rails.

At the end of 1873 the total length of railways in Europe was 63,360 miles, and in the United States 70,650 miles. In his report for 1873, Captain Tyler showed that there were, on the 31st December of that year, 27,564 miles of railway in the British Empire, 16,082 of which were in the United Kingdom, 5,872 in India, 3,899 in Canada, and 1,258 in Australia. In America the increase of railway mileage in prosperous years has exceeded 13,000 miles per annum; and, although there has been a falling-off in the additions made to the railway system of that country during the last two years, American railway journals are confident that five years hence there will be 100,000 miles of railway in the Great Republic. In South America especially there is extraordinary scope for further development, and a number of very extensive additions are at the present moment under consideration. Only a few months ago Sir John Hawkshaw proceeded to Brazil to survey a line of coast extending about 5,000 miles, beginning at Pernambuco, with the view of reporting upon eligible spots for the establishment of harbors and the construction of new railways. Peru now possesses, or will shortly possess, twenty-two different lines of railway, or an aggregate of 2,030 miles, constructed at a total cost of about £36,000,000 sterling. One of the Peruvian railways, now almost half finished—the line from Callao and Lima to Orogo—crosses the Andes at a height of 15,000 feet above the level of the sea. The contract was recently let in this country for the construction of the Lima and Pisco Railway in Peru. This line is intended to connect the towns of Lima and Pisco with the shipping ports of Callao and Pisco on the Peruvian coast, and the Peruvian Government, besides making a concession of the land, have guaranteed £1,040,000 towards its construction. In addition, however, to the great trunk lines still to be completed in America, many connecting railways are under consideration. It is proposed to construct a line from Salt Lake City to Coalville, with the view of connecting the Union Pacific Railway with several important coalfields; and another line, 400 miles long, has been projected from Grand Haven, near Milwaukee, on Lake

Michigan, and Portsmouth on the Ohio River. Of the many other American schemes that have scarcely as yet passed out of the region of speculation it is not necessary to speak; but, in view of the vast resources, agricultural and mineral, of the American continent, it is impossible to assign bounds to the scope for further extension.

On the continent of Europe many new railway schemes are either in progress or projected. At the end of March, 1873, the total length of railways in operation in France was 11,162½ miles, and at the close of March, 1874, the corresponding total had grown to 11,601⅞ miles, so that during the twelve months new railways were opened in France to the extent of 439⅝ miles. Had it not been for the impoverishment of the country, consequent upon the Franco-Prussian war, there can be no doubt that the railway system of France would have been much more rapidly developed; and after the State has to some extent got rid of the incubus of the indemnity, many railways which are now in abeyance for lack of the necessary resources will be taken up. The Russian railway system covered in 1873 a total length of 15,842 versts, of which 5,262 versts were State-owned lines. There were 1,740 versts more in course of conrtruction, and 2,343 versts projected but not begun. There are fifty railway companies in Russia, of which ten only have constructed their lines altogether without Government assistance. The remaining forty are guaranteed—twenty to a partial extent, and twenty more to the full extent of their capital. This system of guarantee has a stimulating effect on projectors, but it is also to some extent neutralized by the fact that the charters granted to railway companies are for the most part terminable after seventy-five to eighty-five years. During the first half of 1874, 411 miles of new railway were opened in Germany, and 205 miles in Austria and Hungary. With the five milliards of French indemnity at their disposal, the Germans have recently exhibited an earnest determination to develop their resources; and although the resources of the Fatherland are limited and inferior in comparison with other countries, there is much latent wealth susceptible of development by railway extension. The Servian Minister of Finance was recently negotiating with an English firm for a loan of 60,000,000f. for the construction of the new railways in Servia, some of which are to be proceeded with forthwith; and the Dutch Government propose to apply the surplus of about 14,000,000fl. shown by the Budget of the Dutch East Indies to the construction of railways in Java. Although Belgium is perhaps as well furnished with railways as any country in Europe, the Government, who own most of the railways, have in view considerable future extensions. They propose to lay down another line from Brussels to Antwerp, and to construct a new railway from Brussels to Willebroeck. During the present year a number of new lines are expected to be opened in Belgium, including a line from Fleurus to Nivelles; another from Blaton to Bernissart, another from Antwerp to Bonn, and another—a branch of the Franceries and Chimay Railway — from Thuillies to Beaumont. Of the new railway extension projected in Great Britain we need not speak—information on this subject being always available—further than to say that "the cry is still they come."

It is, however, in the "wild untrodden wastes" of Asia and Australasia that the expansion of the railway system must chiefly take place in the future. When the illimitable resources of Asia, and especially of India and China, are considered in conjunction with the fact that there is not throughout the whole of that vast continent even half the extent of railway mileage laid down in the United Kingdom, it is impossible to assign bounds to the possibilities of the future. It will be remembered that the Iron and Steel Institute co-operated with the Duke of Sutherland and other gentlemen in sending to the late Emperor of China in 1873 a present of railway stock, with the view of inducing his Imperial Majesty to afford to European capitalists the necessary facilities for introducing the railway system into his vast dominions. It may be that the premature death of the Emperor has hindered the consummation of the object with which this scheme was projected; but it is, at all events, a healthy sign that Mr. Henderson has been commissioned by the Mandarins in charge of the Chinese arsenals, with the authority of the superintendent of trade for the northern treaty ports, to procure the plant necessary for working iron and coal mines, and for smelting and manufacturing iron in that province according to the most improved European methods. This is a step in the march of civilization calculated to lead to results of untold magnitude. Without railways it would be almost impossible to carry on either metallurgical or mineralogical operations successfully; and even the ingenuity of the Celestials will not enable them to prove an exception to this invariable rule. The thin end of the wedge has been introduced, and in this case the first progressive step may be accepted as an augury of others that must shortly follow. India, again, although not like China, closed to railway enterprise, has only made slow progress in the past. Up to the present time the total length of railway sanctioned for our Indian empire, including both guaranteed and State lines, is 7,799½ miles, of which 5,872½ miles are already open, and 1,927 miles remain to be completed. It is well known that M. de Lesseps has for a considerable time past been endeavoring to make terms for the carrying out of a great central Asian railway scheme, with a view to the promotion of which both he and Mr. C. Stuart recently undertook a survey of India; material obstacles of considerable difficulty stand in the way. The route originally proposed was from Orenburg through Samarcand, the Hindoo Koosh, and the Cabool Valley to Peshawur, but in the course of his visit to India M. de Lesseps proved the impracticability of this scheme. He now proposes, therefore, to adopt an easterly route, through the Sir-Daria Valley to Tashkend, skirting the lofty table-lands of Pamir, and passing thence to Kashgar, Yarkand, and Cashmere. In following this route it will be necessary to cross the lofty mountains of Monz-Dagh, the western spurs of the Kuen-Lun, the Karackorum, and the Himalayas. The Karackorum mountains are higher than any yet surmounted, but the gradients are much easier than others that have been successfully crossed by railways in America, and the engineers are of opinion that neither the Karackorum Passes nor the Bolam Pass need terrify them. It has recently been stated that M. de Lesseps is inclined to abandon his project of a line of railway to connect Russia and Central Asia with India in favor of one between Russia and China; but it is also authoritatively stated that the connection with Tashkend with the Russian lines is only a question of time. The opening of the Euphrates Valley route to India is another gigantic undertaking that looms in the future. A committee was appointed early in 1872 to consider the question of railway communication with India, and after examining a number of witnesses and entering at length into the merits of the different schemes proposed, they completely approved not only of the policy, but also of the practicability of the Euphrates Valley route. The cost of this proposed railway has been estimated at ten millions sterling, and the Turkish Government is said to be quite prepared to entertain favorably any proposal made by us for the construction of the line under the control of a joint committee of the two Governments. Turkey, indeed, has recently shown a rare spirit of enterprise and enlightenment in this matter, and a large development of its railway facilities is in prospect. Already the Sublime Porte has authorized the construction of a railway from Kerbela to Bagdad, and has directed the Governor of Bagdad to carry it out. Persia, by annulling the concession made to Baron Reteer, has taken a retrogade step, which may retard the introduction of the railway system within the Shah's dominion for a number of years; but his Majesty saw too much of the beneficial operation of Western civilization during his recent visit to Europe to abandon altogether the projects of advancement which he then formed. In Cape Colony, about 800 miles of railway are about to be constructed at a cost of four or five millions sterling, and in New Zealand there are 550 miles of railway in course of construction and 360 more authorized. It is considered probable, also, that the South Australian Government will before long undertake the construction of a new railway to connect Adelaide with the river Murray. This will be one of a series of lines projected, with the view of connecting the different railways of

Australia, it being intended to make it a grand trunk line, which, at a cost of a million and a half sterling, could be taken from Adelaide to the Victorian border, there to unite with the railway system of the neighboring colony, which is, in its turn, to be connected with the railways of New South Wales.

Were we to take cognizance of minor details this brief survey of the railway prospects of the future might be prolonged *ad infinitum.* Enough, however, has probably been said to demonstrate that the fears are unfounded which point to a falling off in the prospective demand for railway iron. Our manufacturers have not only to meet the constantly recurring demands made upon their resources of production on account of new railways, but they have also to supply the constant renewals required on account of wear and tear of existing lines. The old railway materials, on account of which these renewals will be required, are calculated at six millions of tons in England, three millions of tons in France, ten millions of tons in America, and ten millions of tons in the rest of the world, making a total of thirty million tons of iron rails requiring to be renewed within fifteen years—assuming that period to be the maximum average life of rails made of iron. How is this extraordinary demand to be met? Not, certainly, by the speedy substitution of steel for iron in the manufacture of railway *material.* A complete transition from the one metal to the other may, in the course of years, be accomplished, but it will involve to a considerable extent a revolution in the conditions under which steel is now manufactured, and at the best it will be the work of slow degrees. So far, indeed, as the United Kingdom is concerned, the resources now existent for the production of steel are very limited, while those for the production of iron are illimitable. The only ores that can advantageously and safely be made use of in this country for steel-making purposes are those of Cumberland and Lancashire. It is true that here and there, as in Weardale, and at Ridsdale, in the north of England, ores suitable for steel-making are found, but they are so exceedingly limited and precarious in extent and deposition, that for commercial purposes on a large scale they must be left out of the reckoning. The great bulk of the iron ore of the United Kingdom will not make steel of a reliable kind by any ordinary process now in use. The immense deposits of ore in Cleveland, and the more recently developed ores of Lincolnshire and Nottingham, are quite unsuited for the purpose, by reason of the presence of too much phosphorous and sulphur, and these two vitiating elements cannot be eliminated by any known mode that has yet been proved to yield successful commercial results. Only hematite ores of the purest kind are available for the requirements of the Bessemer steel manufacture, and limited—in comparison with the iron trade—as that manufacture now is, the scarcity of pure hematites at home has necessitated our English steel makers placing their main dependence upon extraneous supplies. Spanish hematite is largely imported into England for the purposes of the steel trade, and ores of the same class, although more costly, are imported from Norway, Sweden, Turkey, Algiers, and other distant places. This inevitable dependence upon foreign sources of supply places the English steel manufacturer at a great disadvantage. An arbitrary enactment on the part of a foreign Government may completely paralyze him. It is true that certain treaties for the protection of the English manufactures are generally entered into before any large amount of capital is invested in foreign mines; but the recent conduct of the municipality of Bilboa, in levying a large duty on Spanish ores leaving that port, in defiance of a treaty made with the imperial Government, is sufficient to show that treaties are not always to be depended upon. With the iron manufacturer the case is very different. His resources are entirely self-contained. More than this, they are practically inexhaustible, and if English masters and workmen only prove true to themselves they could defy the competition, not of Europe only, but of the whole world in the manufacture of iron. We have heard a great deal lately of mountains of iron ore cropping out on the surface of America; but we have practically seen the same phenomena in Lincolnshire—where the ironstone is quarried in the "open"—and in other iron producing districts in this country. Taking one thing with another, England can produce iron considerably cheaper than America, the latter country, notwithstanding her vast resources, being handicapped by the scarcity and dearness of labor.

It is true that the condition of things may be reversed; but for years to come, at any rate, England will be the ironmaster of the world; and in the first part of this article enough has been said to show that the prospects of our staple trade at the present time are not so dismal as many timorous people supposed. In making iron rails, at all events, plenty of work may be found for many years to come.

ROCK ASPHALT AND CONCRETE IN THEIR APPLICATION TO ROAD-MAKING AND BUILDING.*

From "The Builder."

In handing in the title of the subject, I fear that for the moment I did not appreciate the full extent of the ground which such a title covers. To argue the theory and practice of working in cement in its various qualities and methods of manipulation, would be to enter upon a topic of almost undefined extent; so with your good leave I will refer to concrete only incidentally, and make the subject of this paper "Road-making," having special reference to rock asphalt as applicable thereto.

Asphalt, as commonly referred to, is generally understood to mean a rough mixture of broken brick, cinders, gravel or grit, with common tar or pitch. This composition has for many years past been frequently used in the construction of footwalks in quiet neighborhoods, and even sometimes in roadways where the traffic has been very light. It has, however, never been anything like generally used; for although it presents a pleasing effect when first laid down—especially when sprinkled with limestone chippings or other bright facing—a very small amount of wear disturbs the surface and causes speedy failure.

I believe the cause of this early disintegration to lie in the natural principle, that no loose hard material may remain long distributed among any material of a softer nature. Every tread upon a paving of Common asphalt tends to force away the soft material from between the pieces of the hard material, and the effect of this is to leave the hard material less and less perfectly cemented. Moreover, the soft material is readily affected by the heat of the sun, and "comes" and "goes" with each variation of temperature, the effect of which is to reduce its adhesive qualities; for although the heat of the sun is sufficient to loosen, it is not sufficient to quicken and fuse the bituminous particles together again.

Again, not only sand and grit, but particles of common loam and earth, are by the effect of traffic thereupon gradually pressed and worn into a mass, which soon tells with adverse effect upon the quality of the paving. It is well known that the introduction of earthy particles are deleterious to, and detract from, the coherence of any cementing material. In the case of mortar and other quick-setting cements, of course no such adulteration can be effected after they are once hard; but in the case of a cementing substance which never properly hardens, and the very purpose of which is to be trodden upon, such adulteration is perpetual and inevitable, and equally inevitable is its rapid deterioration. In this way may be accounted for the disappointment so commonly experienced in a paving which at first appears so sound and beautiful, but which so soon becomes disintegrate and unsatisfactory. The quality of asphalt to which I make special reference, is that prepared for use by nature herself, which is quarried or got from the mine, and which is as superior to the common asphalt just referred to as a piece of fine

* From a paper by Mr. Edward Guthrie, read before the members of the Liverpool Architectural Society.

marble is in grain to the grain of the coarsest piece of sandstone: it is called rock asphalt. This asphalt is a natural combination of limestone and bitumen. The saturation of the limestone is so perfect, that separation of the two materials cannot be effected, nor by any artificial means can so complete a combination be produced. The proportions of the materials are generally about 92 to 93 parts of lime to 7 to 8 parts of bitumen, with traces of silica or other calcareous substances.

Limestone being developed from deposits of organic matter which in ages past have accumlated in fissures and hollows in the surface of the earth, it is supposed that when such organic matter has become heated during a certain stage of the process of decay, and when it has remained for a lengthened period at a certain high degree of heat, a vapor has been generated which, when confined and unable to escape, has ultimately condensed as bitumen in the mass in which it originated. Considerable deposits of this material are known to exist in many parts of the world; but the mines from which supplies of the best material are obtained are the Limmer Mines near the city of Hanover, and the Virwohle Mines in the Duchy of Brunswick, Germany, and from the Val-de-Travers and Seyssel Mines in Switzerland. The material as got from the mines is of a brownish black color. Where the mines are worked in underground galleries, where the temperature is even—as is the case of the Challenge and Chavoroche Mines—the material is got regularly in a loose earthy condition; but when the mines are open and exposed to the influence of the sun the case is different. It can then be only worked in the cool of the morning and evening, when it is comparatively brittle, for under the heat of the sun the rock becomes so elastic as to be exceedingly difficult to separate.

The use of Rock Asphalt, according to antiquaries, appears to have been known by the ancients, for evidences of its having having been used in building are said to exist among the great ruins of Egypt and Assyria, but in modern times it is only very recently that it has at all become generally known or largely applied. During the last century the material was to some extent introduced, but not until within the last thirty or forty years has any considerable use been made of it. In 1838 it was used for the first time in Paris, in the paving of a street. Since then it has been largely adopted for that purpose in many other large Continental towns, including Berlin, St. Petersburg, Moscow, Riga, and Copenhagen; and very lately, but not till very lately, it has been used in London and other large English towns as a paving. Besides for general paving purposes, it is a material capable of being used with great advantage either alone or in conjunction with cement concrete, in place of slates and lead in roofing, in the construction and lining of reservoirs, cisterns, damp courses, and in sanitary arrangements generally. And while thus (although only incidentally) referring to sanitary arrangements, I cannot let the occasion pass without earnestly urging the attention of this meeting to the facilities which rock asphalt affords for the cutting off of all direct communication between the islands of buildings and the drains. A more unsafe and insanitary arrangement than the introduction of drains to the insides of houses could not well be designed, and with architects rests the practical application of all reforms in this direction. Drains are pipes charged in a greater or less degree with poisonous vapors active for the spread of disease and death, and ever waiting to escape by the slightest imperfection therein, through the various traps laid either in the cellar floors or to the sinks and closets. By the present system of laying cellar floors with brick on edge, tiles, or inferior flagging, it is perhaps almost a necessity to introduce a drain to carry away the moisture which would otherwise accumulate in the lines of the floor, and there stagnate. By the proper application of asphalt all necessity for the introduction of drains into the house may be removed.

In the building of a house, and after carrying the foundation up to the level of the cellar-floors, an inch or ¾-inch layer of rock asphalt should be spread over the whole surface, simultaneously forming the final flooring of the cellars and the damp coursing of the walls; and as the outside walls are carried up, the asphalt should be turned and carried up the outside of such walls to the level of the ground line, forming a perfectly waterproof skin to the whole basement. All washing and other waste water should be carried by a pipe into an outside area in the open air, and should enter the drain by a trap there, which should be as far away as possible from any opening in the house. I would not only suggest that this sanitary arrangement should be made compulsory in the matter of cellar drainage, but would also advise its compulsory application to all upstair sinks and closets, obliging all drainage matter from any source within the house to be conveyed into a trough in the open air before entering the drain, so that no direct communication between the insides of dwellings and drains should exist.

Now, with respect to street paving: I will assume it to be admitted on all sides that for footwalks a half-inch or five-eighths layer of rock asphalt upon a 3-inch or 4-inch layer of Portland cement concrete is superior to flags, tiles, or any other quality of footwalk pavement; and now that the cost of asphalting and flagging are about equal, I believe that the general adoption of asphalting in place of flagging is but a matter of time and emergency. . . . . . .

Wood stands next as a high-class paving. Only in one point—that of foothold—does it stand superior to asphalt; but on this account alone it threatens to compete very seriously with the otherwise infinitely better material. Observations have been made and records kept which prove that in all states of the weather other than greasy, the number of falls upon asphalted roads is fewer even than upon granite sets, and it is obvious that a fall upon a smooth asphalted road, when it does occur, must be less injurious to the horse than a fall upon a rough and stony one. The difficulty, however, of rising from the asphalt after a fall is very great. . . I have from time to time given considerable thought to the end of attaining the desired object; and since I, a month ago, submitted the title of this paper, I have designed and registered a system of paving, a model of which is before you. I take short pieces of lathwood, which, having been first saturated in a preservative of liquor, I pass through a vessel containing rock or other asphalt in a molten and mastic state, and simply place such pieces of wood, with a small portion of the asphalt adhering to each piece, on their ends or edges upon the prepared surface of the ground to be covered, in such a position that they lean upon each other at any angle other than a right angle to the ground covered, and thus let them cool to a solid amalgamate mass, the ends or edges of the laths, closely packed with the hardened asphalt, forming the surface of the road. The road may be rolled, if desired, for fuller assurance of solidity, or for the purpose of giving a dressing to the surface; and I here call particular attention to one of the special features of its construction, that is, the angle at which the wood used lies. It is obvious that a paving so constructed, the more it is run upon the heavier the weights which pass over it, the more and more consolidated it must become, and that a road so constructed must have great durability.

The following facts on the duration of life appear in the *Deutsche Versicherungs-Zeitung*: In ancient Rome, during the period between the years 200 and 300 A.D., the average duration of life among the upper classes was 30 years. In the present century, among the same classes of people, it amounts to 50 years. In the sixteenth century the mean duration of life in Geneva was 21.21 years, between 1814 and 1833 it was 40.68 years, and at the present time as many people live to 70 years of age as 300 years ago lived to the age of 43. In the year 1693 the British Government borrowed money, the amounts borrowed to be paid in annuities, on the basis of the mean duration of life at that time. The State Treasury made thereby a good bargain, and all parties to the transaction were satisfied. Ninety-seven years later, Pitt established another tontine or annuity company, based on the presumption that the mortality would remain the same as 100 years before. But in this instance it transpired that the Government had made a bad bargain, since, while in the first tontine 10,000 persons of each sex died under the age of 28, 100 years later only 5,772 males and 6,416 females died under this age."

GRAPHICS.

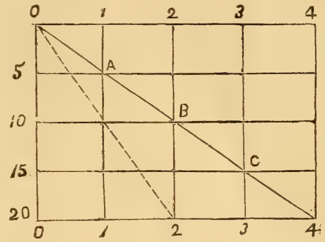
BY GEO. L. VOSE, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE various methods ordinarily employed for the solution of mathematical problems are well known to all who are familiar with arithmetic, algebra and geometry. There is, however, a method of answering a certain class of questions, and of representing certain results, by a direct appeal to the eye, which is extremely simple, very effective, and in some cases superior to every other mode. This process is by no means new to scientific men, but it may be both new and interesting to many persons; and we propose therefore, without further preface, to present a few examples of the graphic method, the extension of which to additional questions will be readily made by the reader.

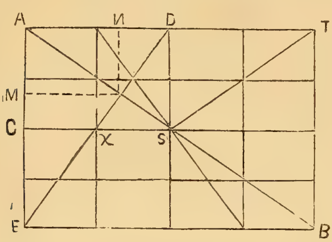
Suppose we have the following question: If a man travels five miles an hour, how far will he go in four hours? This, of course, is the plainest possible question in simple multiplication. Suppose, however, that we have the following problem: A man starts from the foot of a mountain to walk to its summit; his rate of walking during the second half of the distance is half a mile per hour less than his rate during the first half, and he reaches the summit in $5\frac{1}{2}$ hours; he descends in $3\frac{3}{4}$ hours, walking at a uniform rate, which is one mile an hour more than his rate during the first half of the ascent. Find the distance to the summit and his rates of walking. Here, now, is a question which our simple multiplication will not answer; but by the graphic method the second question is nearly, if not quite, as simple as the first.

To begin with our first question above. Draw a horizontal line and divide it into equal parts, as in the upper horizontal line in Fig. 1. Let these equal horizontal divisions represent hours. Through each of the points, 0, 1, 2, 3, etc., on the upper line, draw the verticals 0, 0, 1, 1, 2, 2, etc., and on the first vertical, 0, 0, lay off equal divisions to represent miles, and through the points of division, 5, 10, 15, draw lines parallel to the upper horizontal. We have here *time* laid off on one line and *distance* laid off upon another line at right angles to the first. Now, if our man travels five miles in one



hour, his path is represented on our diagram by the diagonal line from 0 to *a*; any inclined line in the Fig. representing at the same time a movement both in space and time. If we wish to know how far the man will go in two hours, we have only to draw a vertical through 2 until it cuts the diagonal at *b*, and from *b* draw a horizontal line to our vertical scale of miles, which we shall find at 10; or, if we wish to know how long he will be going 15 miles, we draw a horizontal from 15 to cut our diagonal at *c*, and through *c* draw a vertical to cut our time line at 3. If a second man goes twice as fast as the first, his path will be shown by the dotted line, which passes through the intersection of 1 hour and 10 miles. Suppose our question was as follows: Two men start from the same point, one going at the rate of five miles and the other at ten miles per hour. How far apart are they at the end of two hours? We see at once that the vertical distance between our two inclined lines, measured upon the perpendicular through 2, is the difference between 10 and 20 miles, or 10 miles. Reverse the question, thus: Two men start from a given point and travel, one at five miles per hour, the other at ten miles per hour; after a certain time they are ten miles apart; how long have they been traveling? Here we have only to take our vertical distance 10 miles, find where it will just go in vertically between our inclined lines, and produce it until it cuts the time line, in this case at 2 hours. Suppose again that our first man starts from a certain point and at the end of four hours has gone twenty miles; a second man starts at the same time and reaches the end of the twenty miles two hours sooner than the first man; how fast did he travel? In this case we have only to go back on the lower horizontal line from 4 to 2, and draw the dotted line from 2 on the lower line to 0 on the upper line, the inclination of the dotted line gives the rate required—*i. e.*, ten miles per hour. These questions are thus far extremely simple, so simple as to be done in the head by any member of a primary school; but they illustrate the method, which we will apply directly to more difficult problems.

We have seen that differently inclined lines represent different rates of movement. Let us take now another question: A starts from a certain point

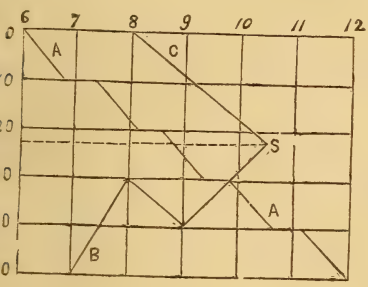


and travels in a certain direction for a certain time; represent his path as before by the diagonal *a b*. B starts an hour later, and passing over the same distance, arrives an hour earlier. How fast did B go, and where and when did he pass A? The dotted inclined line represents B's path, its inclination his rate, and he passes A at the distance *a*, *c*, and at the time *d*. A third man, C, starts from the opposite end of the course at the same time that A leaves his end, and goes at the rate of the second man, B. When and where will he cross the paths of the two other men? It is to be noted that while men may move in the opposite direction, time always goes in the same direction, and even if the man stands still, time goes on. As a matter of convenience, time is always represented as going from left to right. The path of C is therefore shown by the full line from *e* to *d*, and he will pass A at *m* on the scale of miles, and at *n* on the time line; he will pass B on the second horizontal, for distance, and half way between the second and third time lines. Let us alter the question with regard to C, thus: C leaves the opposite end of the route at the same time that A leaves the first end, but travels twice as fast until he has gone half the length of the course, when he stops until B overtakes A and then goes on arriving at A's starting point at the same time that A arrives at his (C's) starting point. What is C's rate during the last half of his course? Here C's course is represented by *e x*, his stops of an hour by *x s*, and the remainder of his course by *s x*, the inclination of which is evidently the same as that of *s b*. C's rate during his last half is then the same as A's uniform speed.

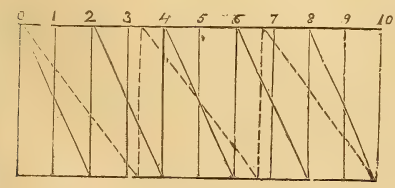
The algebras and arithmetics abound in questions like the following: Edinburgh is 360 miles from London. A starts from Edinburgh and travels ten miles per hour; B starts from London and goes eight miles per hour; when and where will they meet? The reader will quickly answer the question by the graphic method. Here is another question: A privateer running ten miles per hour sees a ship eighteen miles off going at eight miles per hour; how far can the ship go before it is overtaken? Here we first lay off a diagonal representing ten miles per hour; we then go down on the left hand vertical eighteen miles and lay off a second diagonal representing eight miles per hour; these diagonals produced will intersect, giving both the distance required and the time at which the ship will be overtaken. We do not give the figure, as it necessarily takes a good deal of room.

Take the following question: Two towns are 50 miles apart; A is to leave one of these towns at 6 A. M. to arrive at the other at noon, making four stops of half an hour each at 10, 20, 30, and 40 miles from the starting point; B leaves the other end of the road at 7.30, travels twenty miles per hour for an hour, then turns back and retraces his course for an hour at ten miles per hour, then turns back and advances again at such a rate as to pass A as he is starting from his third halt; continuing at the same rate

B meets at half past ten a third man, C, who left the first end of the route two hours later than A did. At what rate has C been traveling, and where did B meet him? To the ordinary arithmetical process this question would seem at least a little "mixed," but it is not in the least so in the diagram below, when B is seen to meet C $22\frac{1}{2}$ miles from A's starting point at half past ten o'clock, and C is found to have been going at the rate of ten miles per hour.

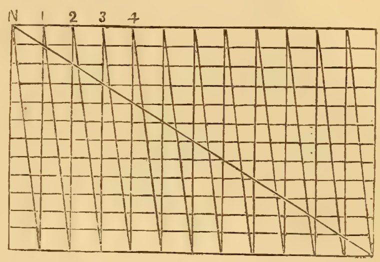


Let us pass now to a somewhat different class of questions: Two men start at the same time to walk round an island; the first man goes $3\frac{1}{3}$ miles per hour, and the second goes 5 miles per hour; the distance around the island is ten miles; how long after starting will the second man pass the first, and how long before he will pass him the second time? The reader will, perhaps, not at first sight see the relation between movement on the circular path and time, as it is a little different from the relation of movement on a straight line to time. He has, however, only to observe that in traveling a circular path a man, while always getting farther away from the starting point, is at the same time getting nearer to it, or he is traveling both from and towards it at the same time. Our question above thus takes the form shown in Fig. 4, in which the first man's

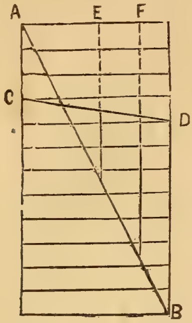


path is represented by the full lines, and the second man's path by the dotted ones. The reader will see at once why having drawn *a b* we recommence at *c*; in going from the point represented by the upper horizontal line to the point represented by the lower one, inasmuch as the path is a circular one, we have got back again to the starting point. The second man, it will be seen, passes the first at five hours, and again at ten hours from starting. If, instead of going in the same direction, one of the men moves in the opposite direction, we have only to start from the lower line and incline the diagonal in the opposite direction; and we may vary their rates of speed and stop them at any points for any length of time without making the question any more difficult.

Let us try the watch problem as given in the algebras, viz.: The hands of a watch are together at noon; when are they next together? In Fig. 5 we have



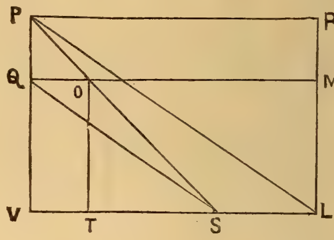
represented the movement of both minute and hour hands for twelve hours, and we shall find that the several diagonals answer a variety of questions. We may take the distance around the face of the watch as representing time or distance, as we please. It represents both, and we thus lay off twelve divisions on the upper horizontal line and on the left hand vertical line. The long diagonal represents the course of the hour hand for twelve hours, and the short diagonal the twelve revolutions of the minute hand in the same time. We see plainly that the hands are together at noon, at a little after one, at a little more after two, still more after three, and so on, the precise time being found by carrying the crossings of the diagonals vertically up to the time line. Our sketch is too small to do this accurately. We find often this question in elementary works upon algebra. The hands of a watch are at right angles at three o'clock, when are they next at right angles? The hands are at right angles when they are fifteen minutes apart. Taking one hour out of the preceding figure, and enlarging it, we find the path of the hour hand, shown by *c d* in Fig. 6, and that of



the minute hand by *a b*. Wherever we can get the vertical equal to fifteen, or to *a c*, in between the two diagonals in a vertical position the hands will be at right angles. The second of these positions is carried up to the time line at *e*, or between 32 and 33 minutes past three. Let the question be to find at what time between three and four o'clock the hands are diametrically opposite. Diametrically opposite is thirty minutes apart; and applying thirty minutes on the vertical scale in Fig. 6, above, to the lines *a b* and *c d*, and producing the line upwards we find the time line to be cut at *h*, or about eleven minutes before four.

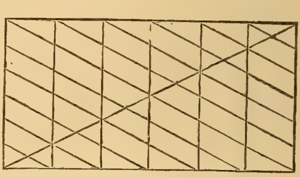
We will add here a problem for the reader, which, with the question regarding the traveler ascending a mountain, given at the commencement of this article, will exercise his ingenuity. Two travelers, A and B, set out from two places, P and Q, at the same time; A starts from P, with the design of passing through Q, and B starts from Q, and travels in the same direction as A. When A overtook B it was found that they had together traveled thirty miles; that A had passed through Q four hours before, and that B at his rate of traveling was nine hours' journey distant from P. Required the distance between P and Q.

Fig. 7 gives the general form of the diagram for the question above, P R being nine hours, P Q the distance required, P V and Q V being together thirty miles, and T S being four hours. Now, P Q must be such that Q S drawn parallel to P L shall cut V L in such a point, S, that a line from S to P shall cut Q M in a point, O, which shall be four hours back of S.



Additional questions may be found in Todhunter's larger algebra.

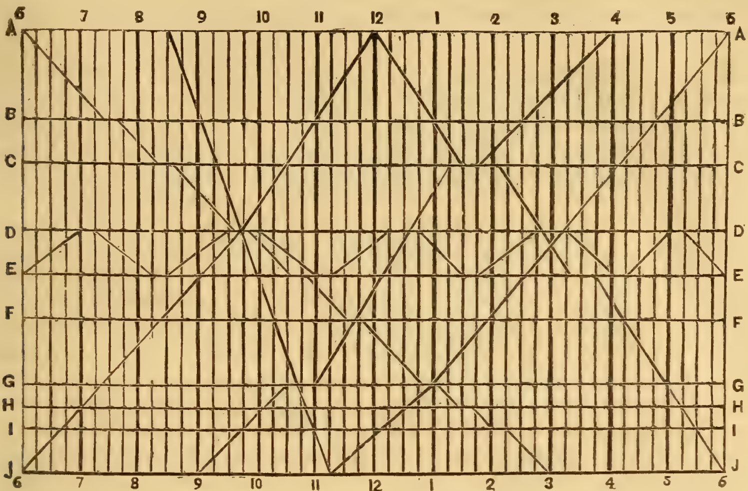
About the time the Union Pacific Railroad was opened the newspapers passed round the following question: Suppose it takes a train just one week to run the whole length of the road, and that one train leaves each end of the route each morning, how many trains will a person meet in going the length of the railway, not counting the train that arrives just as he starts, nor the train that starts just as he arrives. Let the six divisions of the horizontal lines in Fig. 8 represent the six days and the vertical lines the length of the road. The number of trains is at once seen to be eleven.



We will conclude this part of our subject by an application of the above method to a question of great practical importance, viz., the adjustment of the running times of railway trains, the extract from a recently published work upon railway engineering:

Let the heavy vertical lines in Fig. 9 represent the successive hours of the day, and the intermediate finer lines the quarter hours. The horizontal lines represent the several stations along the road, the vertical distances between these being plotted by scale according to the actual distances in miles. Suppose that we wish to start a train at 6 A. M. from the station represented by

A A, so that it shall arrive at station J at 3 P. M., stopping 15 minutes at each way station. The number of way stations being 8, the whole time consumed by stops will be 120 minutes, or 2 hours. From 3 P. M., on the lower horizontal line, go back 2 hours, or to 1 P. M., and from 6 A. M., on the upper



line, draw a line, which produced, would hit 1 P. M. on the lower line. This diagonal reaches the line B B at 7.25. As we stop 15 minutes at the station, we pass along *on the line* B B a distance equal to 15 minutes on the time scale, and from the point thus reached we start again parallel to the first diagonal, arriving at station C at 8.20. Proceeding in the same way we arrive at station J at 3 P. M. as desired. The rate of inclination of the diagonal shows the speed. If we would start a train from A at 8.30 to arrive at J at 11.15, making no stops, it will pass the train above-mentioned at station D, and will run the whole distance in 2 hours 45 minutes. Trains running in the opposite direction are represented on the diagram by diagonals ascending from left to right. Thus, a train leaving station J at 6 A. M. to arrive at A at noon, making no stops, will run, as by the broken diagonal, from 6 A. M., on the lower line, to 12 on the upper one, passing the 6 A. M. and the 8.30 A. M. trains running in the opposite direction at station D. It will be observed that the line from 6 to 12 changes its rate of inclination at the horizontal D, by which we understand that the train changes its rate of speed at that station, running faster from D to A than from J to D.

If it is desired to work a construction train between stations E and D, from 6 A. M. to 6 P. M., the movement of such a train is shown by the short diagonals between the horizontals D and E, and its time card would be thus : Leave E at 6 A. M., and arrive at D at 7. Leave D at 7.15, and arrive at E at 8.15. Leave E at 8.30, and arrive at D at 9.30; crossing the 6 and the 8.30 A. M. trains from A to J, and being passed by the 6 A. M. train J to A. Leave D at 10, and arrive at E at 11. Leave E at 11.15, and arrive at D at 12.15, and wait to be passed by 9 A. M. train, from J to A. Leave D at 12.45 P. M., and arrive at E at 1.30. Leave E at 1.45, arrive at D at 2.45, and pass noon train from station A, and 11.15 A. M. train from station J. Leave D at 3.15, and arrive at E at 4 P. M. Leave E at 4.15 P. M., and arrive at D at 5. Leave D at 5.15, and arrive at E at 6 P. M.

If a train leaves A at noon, and runs towards J, leaving C at 2.05, and reaching E at 3.20, and another train leaves J at 11.15 A. M. and G at 1 P. M., and runs to A, as by the diagonal, without stopping, the trains will pass at 3 P. M. at a point between D and E, the exact position of which may be found by the scale of miles, according to which the length of the road, or the distance A J, is plotted; at which place a siding or passing place must be provided.

Upon a double track road a chart may be prepared for each track, and diagonals in one direction only will appear upon each diagram.

In practice, the diagram is accurately drawn to a large scale, and the several trains are represented by differently colored elastic lines fastened by pins, so that they may be moved from hour to hour through the day and night as the various occurrences on the road may demand; some trains being retarded, others hastened, extras put in, and all provisions made for securing regularity in the movement, and freedom from disaster.

The grades and curves may, if desirable, be shown upon the vertical line A J; by which those parts of the road may at once be seen where, from increased resistance, a lower speed will need to be adopted.

ON RIVER POLLUTION.

By Dr. E. FRANKLAND, D.C.L. F.R.S. &c.

Proceedings of the Royal Society.

In 1865 a Royal Commission was issued for the purpose of inquiring how far the present use of rivers in England, for the purpose of carrying off the drainage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented, without risk to the public health, or serious injury to such processes and manufactures, and how far such refuse or drainage can be got rid of or utilized, otherwise than by discharge into rivers, or rendered harmless before reaching them. Inquiry was also to be made into the water supply of Great Britain.

The Commissioners appointed were Mr. Robert Rawlinson, Mr. John Thornhill Harrison, and Professor Way. Their inquiry extended over three years, and they reported upon the state of the Thames, the Lea, the Aire, and the Calder, and their labors are recorded in three Blue Books with their appendices. This Commission was dissolved in 1868, and a new one appointed consisting of Major-General Sir William Denison, Mr. John Chalmers Morton, and the speaker. They were directed to complete the inquiries entrusted to the previous Commission and to extend them to Scotland. This second Commission finished its work in June last, or in little more than six years, and its labors are recorded in six Blue Books with their appendices.

Besides the inspection of river basins, towns, and manufactories, and the holding of courts of inquiry in the more important towns, these investigations involved the experimental examination of numerous processes for the cleansing of foul water, and the execution of thousands of analyses of foul and unpolluted water. For this purpose a thoroughly equipped chemical laboratory was provided by Government, furnished with every requisite for the investigation of water which modern science could suggest.

To properly consider the great mass of polluting matter which is being discharged into rivers and streams, it will be convenient to classify it into organic and mineral, according to its source and character. Under the head of organic matter we have, first, town drainage; second, drainage from the various forms of fibre manufacture—and under this denomination come paper-making, calico industry, woolen industry, linen and jute industries, and the silk manufacture. Under the head of mineral matter we have, first, mine pollution, or liquids discharged from mines; and, second, drainage from chemical works.

As examples of rivers intensely polluted by each of the above forms of matter may be mentioned the Clyde, which flows through Glasgow, as strongly polluted by town drainage; Dighty Burn, near Dundee, by fibre manufacture; Red River, at Gwythian, Cornwall, by tin mines; and the Sankey

Brook, which flows through St. Helens, is a fair example of pollution by chemical works.

Polluting matter of organic origin presents itself in water in two different forms, viz., in solution and suspension, whereas mineral polluting matter is nearly always present in a state of suspension, and on account of its greater specific gravity will, if allowed sufficient time, subside of its own accord. This is not the case with soluble or suspended organic matter, to get rid of which other means have to be resorted to.

Chemistry is not yet able to determine the actual weight of organic matter which may be present in solution in water. Only two of the principal elements, carbon and nitrogen, can as yet be determined; but the presence of these, even in comparatively small quantity, denotes formidable and offensive pollution.

The Thames may be taken as an instructive example of organic pollution. At its source it is a comparatively pure river. It receives polluting matters from paper factories, and from the drainage of 600,000 people, in its course before it reaches Hampton, and yet it still looks a comparatively clear and pure river. This is owing to the deceptive nature of the polluting matter, which is principally organic, and in solution, and is therefore scarcely discernible by the unaided senses. If, however, it be followed in its course down to London Bridge its pollution becomes apparently greatly augmented, but the organic matter in solution is scarcely perceptibly greater at London Bridge than at Hampton. In short, were the water filtered from the suspended mud stirred up by the steamers and currents, it would, chemically speaking, be nearly as pure at London Bridge as it is at Hampton.

Another instructive case is the Aire, which rises in Yorkshire, a very clear and beautiful river; but before it reaches Leeds it receives, besides the house drainage of more than a quarter of a million of people, the refuse from the following factories:

1,341 cloth and woolen factories, 1 silk mill, 1 flax mill, 10 cotton factories, 7 paper mills, 26 tanneries, 13 chemical works, 8 grease works, 4 glue works, 35 dye works.

At one of the woolen factories alone the following materials are annually used:

Logwood and other dye woods, 320,000 lbs.; chloride of lime, ammonia, and sulphuric acid, 15,000 lbs.; Gallipoli oil, 40 to 50 tons; soap, 70,000 lbs.; alkali, 40,000 lbs.; and 14,000 tons of coal.

With the exception of the last item, nearly the whole of these materials are discharged into the river, and the ashes of the coal also find their way into the same convenient channel of transportation.

At Leeds this mass of pollution is reinforced by the drainage of 300,000 people, and by refuse materials from the following factories:

224 cloth and woolen factories, 62 dye works, 6 dye-wood mills, 25 flax mills, 7 soap works, 1 silk mill, 28 tanneries (which tan 2¾ million hides annually), 29 chemical works, 10 carpet factories, 3 glue factories.

The history of the river Calder, which joins the Aire lower down, is similar; but this river is less intensely polluted. After receiving the drainage of all the towns and factories on its banks, its water is pumped up for the supply of Wakefield.

The condition of the water may be judged of from the fact that a local manufacturer was able to write and dedicate a memorandum to the Local Board of Health with a pen dipped in the river water.

Now these two rivers—the Aire and Calder—the one running from Leeds, and the other from Wakefield, meet at Castleford, and there they fall over a high weir. At this spot the pollution of the water is so great as to blacken the very foam on its surface. Yet, these streams must, at one time, have been celebrated for their cleanliness and purity; otherwise the well-koown couplet would scarcely have been written:

"Castleford lasses may well be fair,
Wash'd in the Calder and bathed in the Aire."

The effect of bathing in these waters in their present condition would scarcely be so satisfactory.

The accounts of pollution just mentioned are those from town drainage and fibre factories, and these are essentially all organic. The pollution from mines and chemical works, with few exceptions, is mineral, and in suspension.

In the neighborhood of mines the amount of mineral matter present in rivers is sometimes very great. There the ore and matrixes are crushed together into an impalpable powder, then washed with water to separate the heavier metallic matter from the rocky matter. The effluent water from the settling pits is very muddy, and often contains poisonous matter in suspension. This is especially the case in lead mines, where considerable quantities of galena and carbonate of lead, carried down the streams during floods, are washed on the adjacent land, where cattle are grazed. The consequences resulting from this display of ignorance and carelessness are, that the farmers whose lands are washed by these poison-charged waters suffer the loss of cattle and poultry, whilst the profits of the mines leak silently away. At a lead mine in Northumberland nearly 7 tons of lead ore, worth £12 per ton, are thrown away in every 100 tons of waste material. At another time in the same county 2 tons of lead ore, and more than 9 tons of zinc ore, are thrown away in every 100 tons of waste. In the Welsh mining districts there are also many examples of similar careless waste. These metalliferous "skimpings" and muds poison the rivers for many miles, carrying destruction to animal life. Mud containing as much as 5, 9, 13, and even 25 per cent. of lead ore is not unfrequently found in the neighboring streams.

Such is the pitiable plight to which many of our formerly beautiful rivers have been reduced, and now the question confronts us—What are the remedies for this grievous nuisance? Fortunately, science gives no uncertain reply to this question. Indeed, for one form—the casting of solid rubbish into streams—common sense, without the aid of science, supplies the answer. Such rubbish is laboriously and intentionally carried to the bank and shot into the stream, and its prohibition, under adequate penalties, needs only to be enforced.

The chief sources of river pollution are, first, town drainage and fibre manufacture; and, secondly, pollution by mining operations and mineral works. These are essentially different in their character, and require distinct remedial measures.

Before proceeding to investigate the various remedies which have been proposed for the first species of pollution, it is necessary to be quite sure that artificial remedies are necessary, and that Nature does not herself perform all that is really requisite for the purification of streams. It has been long a theory that polluted rivers cleanse themselves, and that if you pour into them foul organic matters, the latter are rapidly destroyed, and, after a flow of twelve miles or so, the rivers purge themselves completely from the stain, and regain their pristine purity—an exceedingly comfortable doctrine, if true. This theory is in great repute amongst two classes of persons—first, those who are polluters of rivers; and, secondly, water companies who abstract their beverage from points below the outfalls of town sewage. Now considering that this is an exceedingly important question, the Commissioners submitted it to very close investigation. They experimented upon the Irwell, below Manchester; the Mersey, below Stockport; and the Darwen, below Blackburn. They took samples of the water at particular points of the rivers, and then at other points lower down, after a flow of a considerable number of miles, and before any other polluting matters had entered the stream. Thus, they took samples of the Irwell below Manchester, then eleven miles lower down, and found, that while there was a reduction in the organic matter in suspension, there was, practically, no diminution in the quantity in solution. The organic matter in solution was comparatively unaffected — certainly not destroyed, although the river falls over nine weirs, and is thoroughly aërated. The same results, substantially, were obtained in the Mersey, where there was a 13-mile flow available, and also in the Darwen, where there was also a 13-mile flow.

But it might be said that, in the case of these rivers, the pollution is so intense, that neither animal nor vegetable life can exist in them, and that it is the action of animal and vegetable organisms in water which destroys these pollutions. The Commissioners, therefore, resolved to repeat their experiments upon a river water in which pollution was much milder, and for this purpose selected the Thames. They took first a sample of the Thames below Reading, after it is joined by the Kennet, and where it is polluted by the drainage of Reading.

Sufficient time was allowed for the river water to flow to a point four miles lower, and between these points no fresh polluting matter gained access to the stream. After this flow they found the quantity of organic matter in solution and suspension exactly the same as at the beginning, although the quantity of mineral matter in suspension was considerably reduced. Thus it will be seen that these experiments completely dispose of the theory of self-purification.

The methods which have been proposed for remedying organic pollution may be conveniently divided into, first, methods of precipitation; and, secondly, methods of oxydation.

Amongst the methods of purification those by precipitation have been most talked about, because they are the most easily applied on a small scale, and are, therefore, more easily made the subjects of experiment. One of these is precipitation by lime. Most drainage water contains bicarbonate of lime. This is decomposed by slaked lime or lime-water, and the resulting chalk precipitate lays hold of and carries down with it any particles of suspended matter that may be in the water. But it does more; it acts by surface attraction, and actually takes out of solution some of the organic matter which was dissolved in the water. Yet the purification by this means is very imperfect as regards the soluble organic matter.

There is, again the A B C process, which consists in precipitation by means of a mixture of alum, clay, and an infinitesimal quantity of blood.

Then we have the sulphate of alumina method, or Bird's process; (lime and clay), or Scott's process; (lime and chloride of iron, and superphosphate of alumina and slaked lime). All these methods have failed to achieve the end in view.

They are useful in diminishing the suspended matter, but as regards purification from the worst form of pollution, viz. organic matter in solution, they are of little effect.

They have all had their origin in two erroneous ideas. First, that the foul matter in sewage can be removed by chemical means; and, secondly, that the matter actually thrown down or precipitated is valuable as manure. In every case in which it has been tried the precipitated matter is not worth the carriage for more than a mile or two, so that it is practically worthless. In fact, the manuring constituent of this foul drainage is left almost intact in solution. By General Scott's process, however, the precipitated matter is converted into a valuable cement.

The great lesson taught by all these comparatively abortive attempts is, that surface attraction is capable of effecting that which chemical affinity is incompetent to achieve. These are not cases of chemical affinity. There is no fixed relation between the matter precipitated and the precipitant. They are clear cases of surface attraction; but the vast quantities of purifying ingredients necessary to make them really efficient would involve so great an expense as to render them impracticable. Purifying material in each case is manufactured at great cost, and is laboriously carried to the sewage, and fished out again and dried at still greater trouble and expense. This, however, would become of secondary importance if the end desired were accomplished. But this is not the case; the foul liquids are not cleansed. These purifying materials, chalk, alumina, and oxide of iron, and other porous substances exist, however, naturally in all porous soils, and sewage will run to them by its own gravity. These materials are capable of removing nearly the whole of the polluting matter brought into contact with them. We are thus led, by a process of scientific induction, to purification by irrigation. Foul drainage is, in irrigation, mixed with vast quantities of soil, which, by surface attraction, remove from it its polluting matter, both in solution and suspension. Its fertilizing matter is also removed to a great extent, and the roots of growing plants ramifying through the soil, gather up and transform the polluting materials into healthy living tissues, thus preventing the pores of the soil from getting clogged and consequently useless for purposes of purification.

No one visiting Aldershot Camp can fail to be struck with the emerald tint of the irrigated land, contrasting as it does with the sterile soil around it. Upon the land used for the purpose of purification by irrigation every variety of crop can be grown, and at the Barking farm we can actually realize in the summer season the drainage of London transformed into strawberries and cream.

For the purpose of irrigation one acre of land is requisite for every hundred persons contributing to the drainage, and, when properly conducted, there is no nuisance. The only drawback to irrigation is the difficulty and sometimes the impossibility of obtaining sufficient land suitable for carrying on the process near large towns, and the absurdly high prices claimed for such land. This led to the experiment of making a given area of land do more work. After continuous filtration, however, the pores of the soil became clogged up, and the effluent water consequently not purified. The Commissioners therefore availed themselves of a well-known property of porous matter, its attraction for gases, especially for atmospheric oxygen, and the great chemical affinity of this oxygen for organic matter. Spongy platinum possesses this property in a very high degree, and they were sanguine enough to hope that it might also be possessed by porous earth, to an extent sufficient to cause the slow but complete combustion of foul drainage matters.

Their expectation was not disappointed; experiments made upon sewage in their laboratory, and afterwards on the large scale of Merthyr Tydvil, show that by bringing air and drainage water alternately in contact with the soil, rapid, continuous, and satisfactory purification was obtained. Indeed, the effluent water from the Merthyr drainage subjected to this process of purification is, chemically, purer than the water supplied by some of the London water companies.

This process is equally applicable to the discharges from fibre factories of various kinds. It has been carried on for three years at Merther Tydvil, where the drainage from each 3,000 people has been cleansed upon a single acre of land. Crops may be also grown upon the land so used.

The Commissioners believe, as the result of their inquiries into these remedies for organic pollution, that the sewage purification of the future will be irrigation, but for the present, intermittent filtration is safer as regards expense. Neither process is any nuisance to the surrounding neighborhood, but the carrying on of sewage farms by Corporations or Local Boards is a thing not likely to pay; amateur farming rarely does. By the process of intermittent filtration the original expense is much smaller as regards the quantity of land required. In the one case 30 acres are required for 3,000 people, in the other only one acre for the same number.

For mining pollution the remedy is exceedingly simple, viz., subsidence in properly constructed tanks for six hours. The resnlt, though not in every case quite satisfactory, is sufficiently so to prove that the amount of mining pollution in many of our rivers would, by its adoption, be substantially abolished. Even in the case of drainage from coal washing, the polluting matter after subsidence was reduced to a very small amount.

These plans would be sufficiently effective for the treatment of the chief kinds of town, manufacturing, and mining drainage. But it is quite necessary, in any legislative enactment to secure the better treatment of rivers, that there should be some definition of polluting matter. The Commissioners gave great attention to this point, and have proposed after much deliberation the following definitions of polluting liquids:

(*a*) Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size, for a period of at least six hours, or which, having been so subjected to subsidence, contains in suspension more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid; or which, not having been so subjected to subsidence, contains in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b*) Any liquid containing, in solution, more than two parts by weight of organic carbon, or three parts by weight of organic nitrogen in 100.000 parts by weight.

(*c*) Any liquid which shall exhibit by daylight a distinct color when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d*) Any liquid which contains, in solution, in 100,000 parts by weight, more than two parts by weight of any metal, except calcium, magnesium, potassium, and sodium.

(*e*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than .05 part by weight of metallic arsenic.

(*f*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

(*g*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h*) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

(*k*) Any liquid exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing, in suspension, in 100,000 parts, more than .05 part of such oil.

In any enactment for the correction of river pollution, the above standards may be safely qualified by the following proviso: Provided always, that no effluent water shall be deemed polluting if it be not more contaminated with any of the above-named polluting ingredients than the stream or river into which it is discharged.

Of these standards the first two are by far the most important—the standards referring to suspended matter, and to the quantity of organic carbon and organic nitrogen which ought to be allowed to be transferred into streams. These supremely important standards, if enforced by proper and judicious enactments, giving sufficient time for manufacturers to carry out improvements necessary for the purification of foul drainage, would, we believe, abolish fully nine-tenths of all the river pollution by which our streams are now affected in Great Britain. But without the enforcing of the first two standards, this gigantic and growing evil, which is becoming greater and greater every year, will not be perceptibly diminished.

These investigations, extending over nearly ten years, show that the rivers of Great Britain are, in a very large number of cases, fouled and destroyed, not only for domestic, but also for manufacturing purposes, so that the extent of our manufactures is limited by the inadequate supply of pure water; and no people complain more loudly of this pollution than the manufacturers themselves, and none are more ready to adopt judicious measures for removing it. Various manufacturers have spoken of the value of the streams for them, if purified to the extent just specified, some of them estimating it at £1,000 per annum.

On the one hand, while the Commissioners have established this gross abuse of rivers where manufactures and mines are carried on, they have, on the other hand, very good reason to anticipate that a comparatively mild form of legislation, if firmly enforced, would have the effect of restoring many of the rivers to nearly their original purity. To make them pure for drinking purposes is, perhaps, impossible; but it may reasonably be hoped that they may become sufficiently so to delight the eye and to repress the pestiferous and sickening exhalations which at present affect the multitudes of our population compelled to pass their lives on the banks of such rivers.

AERONAUTICS.

By Mr. CHAS. P. LEAVITT.

Written for Van Nostrand's Engineering Magazine.

There is an undoubted fascination about the science of Aeronautics, that has caused large numbers of eminent men to devote more or less time to its consideration. Practical engineers, who have no appreciation for anything that does not bring in dollars and cents, laugh at this. While from the dollar and cent point of view, Aeronautics is a science beneath consideration. Still, in the eyes of those less given to the flesh pots, who have an interest in science for its own sake, the subject is not without interest.

A proper understanding of the laws of Aeronautics would enable us to calculate the conditions requisite for flight with the same certainty as we calculate the dimensions of an engine, or a ship, and the same certainty would exist in the one case as in the others. Nearly all of the investigators in this field have endeavored to discover the proper proportions of a flying thing, without paying any great attention to the laws upon which these proportions are based. It has been assumed that the fundamental laws of aerial locomotion are so complex as to be quite beyond the grasp of the human reason, and hence that the best we can do is to follow as nearly as possible the proportions of natural examples. Another class of investigators have considered that the only way to arrive at the result was by the means of blind experiment.

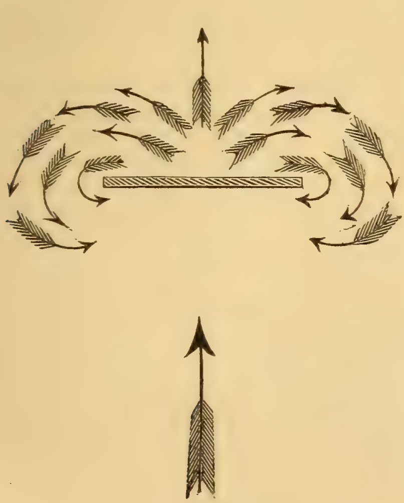
It is evident, however, that sooner or later the mathematics of Aeronautics must be considered, and the writer believes that their consideration at this time will go far toward the practical solution of the problem of artificial flight, should that solution be proven desirable.

The whole subject is extremely simple. In considering the flight of a bird we know that the bird must be supported. We know that, such is the mobility of the air, that there can be no static transmission of the bird's weight to the earth, and hence, we know the bird can only be supported by the reaction of the air, which is given a downward motion by the bird's wing. Knowing the speed of this wing, we know the speed of the air, and hence, by the laws of inertia, we know the weight that is moved to support the bird by its reaction. Again, from the wing speed, or the speed of the air, we know the *power* required to be exerted by the bird to sustain itself—*i.e.* to move per second a given weight of air at a given speed. We might dismiss the subject here as requiring no further elucidation, as far as the method of investigation is concerned, were it not for the confusion existing in published works on Aeronautics in regard to the mathematical expression of wing resistance.

Thus we are told by one writer that a man ought to fly with 100 square feet of wing—which is simply bosh.

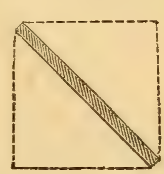
The expressions for atmospheric resistance are all expressions of inertia, except where the air is confined within a cylinder. We may consider the air as a weight in motion arrested in a given time, or as weight moved in a given time. There is a phenomena, however, connected with the movement of planes in air that modifies the element of power required to move the plane. That is, that the power required to propel a plane against the air in order to derive support from a given plane during a given time may be nearly twice as great in one case as in another. Thus let 32.16 feet per second be the velocity acquired by a weight falling 16 feet (one second of time)—then, if we take a pound weight, moving with this velocity, and arrest it in one second, it will exert a force of one pound in that time If we put the weight in motion again it will resist by its inertia one pound for one second, and the power we exert is 16.08 foot pounds. Now, premising that 13 cubic feet of air weigh one pound under ordinary conditions, let us repeat this experiment with air. First, let the air be moving 32.16 feet per second. In order that a fixed plane shall arrest the motion of one pound of air per second, it is necessary that its area be $\frac{13}{32.16}$=.4042 square feet.

The pressure upon this surface is one pound, or at the rate of 2.474 per square foot. If now we take the same plane, and drive it through still air with a velocity of 32.16 feet per second the resistance is the same. The *power* required, however, is evidently 32.16 foot pounds per second. We have seen, however, that to put a weight of one pound in motion with this speed, only requires *half* this power. Since it is utterly impossible to store different quantities of energy in two bodies of equal weight, moving with equal velocity, it becomes a question how the surplus energy exerted in the latter case has been absorbed. We find it in the side motion given to the air. This is shown in Fig. 1. If we move a plane in still air the motion of the air is in the direction of the arrows —it slides sidewise and flows in behind the plane as shown. We know that these side currents are equal in their sum to the foreward ones, and hence the angular motion of the air prevents it attaining a foreward speed equal to that of the plane—hence the resistance of our suppositious plane is not quite one pound. By the corrected rule as determined by experiment, we find the resistance per sq. foot$=32.16^2 \times 002288 = 2.366$ instead of 2.474. The manner in which a bird prevents the formation of these side cur-

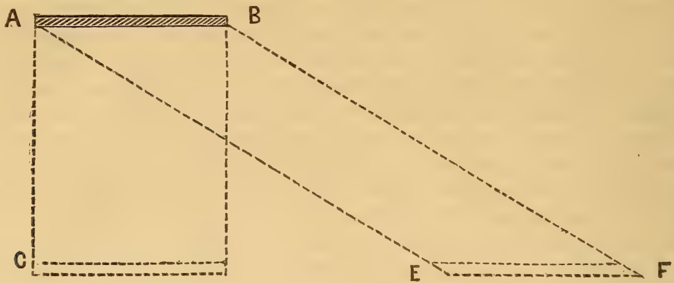


rents, and thus economizes nearly half the energy that would otherwise be required for support, is interesting. It will be noticed, in Fig. 1, that the side currents are opposite, and if they could be connected one would counteract the other. The bird accomplishes this feat in the following manner: At the same time the wing is driven downward, the bird is sliding over the particles of air with a four-fold speed. A particle of air moved by the front edge of the wing takes up a foreward as well as a downward motion; the bird, however, moving over this particle faster than the particle moves forward, brings the particle at once under the influence of the hinder edge of the wing, where the side thrust is in the opposite direction: the momentum already acquired by the air in a foreward direction counteracts this, and by the time that momentum is absorbed the wing has left the particle altogether. The rear half of the wing having to give a force to *moving* air, equal to that given to *still* air by the front edge, the wing must be concave on its under face, precisely as the face of a propeller should be concave, or have an expanded pitch. In this manner the motion of a bird's wing is transmitted to far larger masses of air than would otherwise be possible. The degree of concavity of the wing depends upon the ratio between the wing speed and the foreward speed of the bird.

In considering the effect of foreward motion upon wing resistance, we have to consider another fact. Although the resistance to a continuously moving wing, is expressed as the inertia of successive particles, still, at the first instant of the motion a different element exists. Thus, in Fig. 2, the movement of the wing

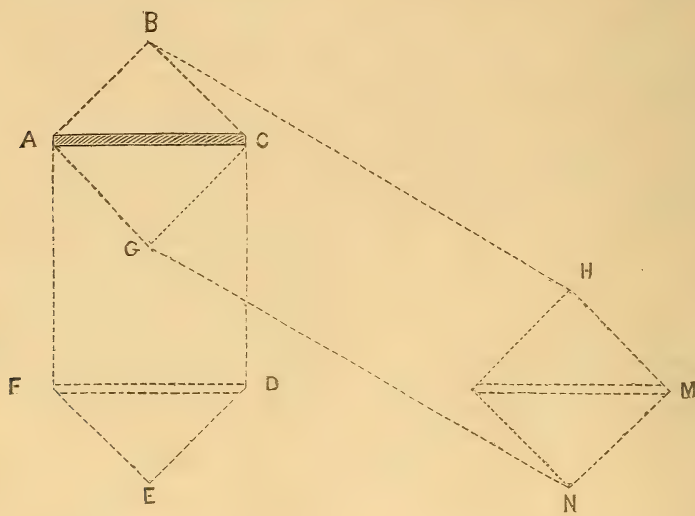


moves *at once* a mass of air represented approximately by the dotted lines. We calculate the inertia of this mass as though it were a solid body, and it will be noted that its quantity is expressed as a cube. *After* that first instant the air is moved as before stated, the wing moving the first quantity as 'dead' air in front and behind. It is to this dead air only that increased wing support while the bird is moving forward is due; this is shown in Fig. 3 and Fig. 4. In Fig. 3, where we consider only the impact of air upon the wing, disregarding the dead air, let the wing *a*, *b*, sweep down to *c*, *d*, then the resistance to the wing is the inertia of the mass of air *a*, *b*, *c*, *d*. Then let the same wing move foreward to *e*, *f*. As it descends, there is no increase of resistance for *a*, *b*, *c*, *d* is equal to *a*, *b*, *e*, *f*.



In Fig. 4, however, where the action of the dead air is considered, *a b h m n e* is very much greater than *a*, *b*, *c*, *d*, *e*, *f*. When we come to consider the facts relating to the flight of a bird, we will see clearly that this phenomena plays an important part in flight, by enabling the bird to move the air substantially as a solid body is moved.

Following out the idea of applying the



mathematical method of analysis to the solution of the problem of flight, we wish to discover from a given example—1st, the power required for flight; 2d, the weights of air moved.

We find in Pettigrew's work upon "Animal Locomotion," p. 134, the following data upon the gannet. We assume the foreward speed:

Weight of bird, 7 lbs.
Length of wing, 2¾ feet.
Area of both wings, 435 square inches.
Foreward speed of bird, 20 miles per hour.
Number of pounds weight to each square foot of wing, 2.3 lbs.
Down beats of wing per minute, 150.
Mean effective width of wing, about 7 inches.

Power of Bird.

Since the ordinary arc of vibration of wings is about 60°, we see from the above data that the centre of percussion of the wing moves at the rate of 500 feet per minute. The bird being supported by the wing, there must be a force of 7 pounds exerted constantly upon the air, or 14 lbs. for half the time, or 21 lbs. for $\frac{1}{3}$ the time, &c. Hence the power exerted by the bird is $500.\times 7.=3500$ foot pounds per minute. This is the power exerted, both for support and for propulsion, for, the observed wing speed includes both elements, since the weight of the bird furnishes the "fulcrum" for propulsion as well as for support. In other words, a bird is propelled not by a rowing action of its wings, but by the force of gravity acting upon an inclined plane furnished by the wings. There could be no rowing action of the wings unless the wing speed exceeded the foreward speed, whereas it is less than one-third as great. The greater the incline, the more rapid must be the wing motion, since support is only given by the wing descending faster than the incline. The degree of this incline is not great as we see as follows :

At a foreward speed of 20 miles per hour, the atmospheric resistance to a flat plane is 1.97 lbs. per square foot. The shape of the bird must reduce this to at least .6 lbs. per square foot, for we know that in well built ships the resistance is only one-ninth that due to this cross-section. The cross-section of the gannet being taken at one foot, we see the resistance is only $\frac{6}{10}$ lbs., and the angle of incline to overcome this is, therefore, 6 to 7 only the downward speed of wing due to this incline is $1760\times\frac{.6}{7}=150$ feet per minute, leaving an actual downward speed of air of $500-150=350$ feet per minute. The absence of exact data as to what the foreward resistance of the air really is leaves this result somewhat doubtful, but the estimate is probably very close. The *exact* figures could be obtained by observing the thrust of the wind upon a bird suspended with outstretched wings.

By observing a bird in flight, it will be observed that the bird derives a constant support, since it does not rise and fall in flight to any great degree. Hence, the wings support the bird both in rising and falling, and, as a consequence, the air is driven down in a constant stream. In rising the wings must support the bird by a kite like action, and this must reduce the foreward speed. On the down stroke the speed must be restored, and since the last speed is equal in terms of energy to the energy required for support during the down stroke, the air on the down stroke must be driven backward with a velocity equal to its downward velocity. These horizontal movements do not cause any variation in the down speed of the air, else the bird would oscillate in a vertical line—neither do they cause any variation in the statement of the power of the bird—the bird merely, instead of supporting double its weight for half the time, stores, in its momentum, on the down stroke, an energy equal to that required for support during that time. The variation of the angle of wing to do this is about 6° when the bird is moving 20 miles per hour.

Weight of Air Moved.

The movement of air being, as we have seen, 350 feet per minute, or 6.8 feet per second, we find that it is moved at a speed in relation to gravity represented by $\frac{6.8}{32.16}$, and hence the total amount of air in cubic feet moved by the bird must be $\frac{32.16\times 7\times 13}{6.8}=430.4.$ cubic feet per sec.

The wings being 6 feet from tip to tip, and the foreward speed of the bird being 29.3 feet per second, we have for the thickness of the strata of air moved

$$\frac{430.4}{29.3\times 6}=2.448 \text{ feet.}$$

Here, we have a 7-inch wing moving a strata of air 27 inches thick. This effect is due solely to the curve of the face and the rapid foreward motion, resulting in a purely down force, practically without side currents.

It will be interesting to compare this result with those obtained from the heron : a bird of half the weight, but with nearly the same wing as the gannet —we credit data to the same work :

Weight of bird, $3\frac{1}{4}$ lbs.

Tip to tip of wing, $5\frac{3}{4}$ feet.
Down beats per minute, 60.
Speed, 20 miles per hour.
Mean width of wing, 9 inches.
The power exerted by the bird is then

$$\frac{20 \times 120 \times 3\frac{1}{4}}{12} = 750 \text{ foot lbs. per minute.}$$

Speed of the centre of percussion of wing, 3.33 feet per second.

If we subtract from the apparent speed one-third as approximately representing the angle required for propulsion, we have for the mass of air moved per second

$$\frac{32.16 \times 3.25 \times 13}{2.22} = 6.12 \text{ cubic feet.}$$

The thickness of strata is

$$\frac{5.75 \times 29.3}{612} = 3.6 \text{ feet.}$$

Here we see that while a 7-inch wing moved a strata 27 inches thick, a 9-inch wing moves a strata 43 inches thick.

A consideration of Fig. 2 indicates that if the air could be renewed instantly beneath a wing, its efficiency would be as the square of the breadth. In the case under consideration, however, it is evident that the efficiency is directly as the breadth, hence the depth of air moved by the heron should be $\frac{9}{7} \times 27 = 34.7$ inches. A very slight variation in the angle required for propulsion in the data, so as to allow the air to be moved down with a velocity of 2.78 feet per second, instead of 2.22 feet, would make the efficiency of the two wings directly as their breadths.* It is likely that a more careful rate of wing speeds would establish some such law. The precise determination of this point depends upon the accuracy of data in regard to speed of flight, weight of bird, area of wing, and speed of wings.

It is evident that the power required for support is inversely as the velocity, and the power for propulsion is as the cube of the velocity. From this it follows that there is a certain speed where the least exertion is required to maintain flight. These facts indicate that flying machines should be of the least possible cross-section, and should be specially designed to offer the least possible resistance to a foreward motion.

No human being can ever fly by muscular exertion, for the gannet, weighing 14 lbs. exerts in flight nearly the power of a man. Taking the extreme power of a man at 200 pounds lifted 2.5 feet per second—a power that could not be maintained for more than a few seconds, we find the cubic feet of air required to be moved at this rate per second to support 200 lbs. thus

$$\frac{32.16 \times 200 \times 13}{2.5} = 33444. \text{ cubic feet.}$$

Stringfellow's steam-flying machine had thrice the power of the gannet, more wing surface than the heron, and weighed but 12 pounds—yet it could not fly because its edge resistance limited its foreward speed, or rather because the edge resistances largely exceeded the driving surfaces. A better piece of mechanism, or a worse piece of engineering probably never was constructed. It had three square feet of sustaining surface for each pound weight, and power enough to lift itself at the prodigous rate of 14 feet per second. Nothing could furnish a better illustration of the point we wish to make, and that is, that crude experiments can never take the place of mathematical investigation, even in Aeronautics.

* It will be understood that the foreward motion of the birds, being a pure assumption, the results of this article are subject to correction when the actual speeds are determined for the given wing beats.

THE MANUFACTURE OF STEEL.*

From "Engineering."

WITHIN the last twenty years the meaning of the term steel has undergone a great change. Dictionaries defined it as iron containing a small proportion of carbon, and Dr. Percy repeated the same definition, giving 0.5 to 0.65 per cent. of carbon as the limit at which iron passed into steel. Such a material was not, however, what was meant by steel boiler plate or a steel rail. The steel of a boiler plate contained less carbon than many samples of wrought iron, and was equally soft and ductile. The difference between it and wrought iron was, that it had been melted and cast into a malleable ingot. This new use of the term steel had grown out of the great increase, of late years, of the production of cast steel of all kinds, almost to the exclusion of other varieties of highly carburetted malleable iron.

Steel might then be defined as any variety of iron that was cast into a malleable mass; and the two parallel series, the irons and the steels, might be classified as follows:

Percentage of Carbon.			
0 to 0.2	0.2 to 0.35	0.35 to 0.55	0.55 to 1.50 or more.
Series of the Irons.			
Ordinary irons.	Granular irons.	Steel irons or soft puddled steels.	Hard puddled steels. Cemented steel. Styrian steel.
Series of the Steels.			
Extra soft steels.	Soft steels.	Half soft steels.	Hard steels.

Steel was made by producing a melted alloy of iron, containing a smaller proportion of carbon or other hardening elements than cast iron.

Practical steel-making processes were of three kinds:

(*a*) Fusion in crucibles, producing crucible steel.

(*b*) Blowing air through melted cast iron, producing Bessemer steel.

(*c*) Fusion on the open hearth of a reverberatory furnace, producing Siemens or Siemens-Martin steel.

Fusion in crucibles was the simplest and oldest mode of making steel, and had been practised by the Hindoos from a remote period. In the Hindoo process, wrought iron was melted in small crucibles, with one-tenth of its weight of dried wood, producing a very hard steel, with upwards of 1.6 per cent. of carbon.

It did not appear that any mode of making true steel was known in Europe before the last century. Reaumur announced, in 1722, that he had made steel by melting together from one-fourth to one-third of malleable iron, with cast iron, in a common forge; and Huntsman, between 1750 and 1770, succeeded in making steel by melting cemented or converted bar iron. Since Huntsman's time the processes of crucible steel melting had been improved only in points of detail, and by the trial or practical use of all the different materials for melting that an advancing knowledge of chemistry had suggested as capable of producing steel. Malleable iron was melted by itself, if it was of the hardness needed to produce the required quality of steel, or it was mixed with carbon or cast iron, if too soft, or with oxide of iron or of manganese, if too hard; and spongy reduced iron, or iron ore, was melted with carbon or with cast iron.

The two principal types of modern pot-steel furnaces were the pot-hole, fired with coke, and the regenerative gas furnace.

Each coke hole held two crucibles, and was a simple rectangular chamber, open above, and communicating near the top with a large main chimney flue. The tops of the furnaces were level with the floor of the shop, and the grates were accessible from the cave below. The pots lasted three rounds, and held from 50 lbs. to 70 lbs. the first round, and from 5 lbs. to 10 lbs. less each time they were charged. The consumption

* A paper read before the Institution of Civil Engineers by Mr. Wm. Hackney.

of fuel was about 3 tons of coke, equivalent to 4½ or 5 tons of coal, per ton of steel melted.

The regenerative gas furnace, for crucible steel-melting, was a long trench, divided by cross walls into two, three, or four sections, each holding six pots. The pots rested on a bed of coke-dust, spread over the bottom of the melting chamber. The saving of fuel effected by the gas furnace was very great, 30 cwt. of small coal, per ton of steel, doing the work that on the other plan required 3 tons of coke.

Pot steel was looked on as the highest quality for all purposes. To some extent this was the result of habit, as pot steel was the oldest and best known variety; but it had also two advantages over other qualities — first, it was or might be made of purer materials, as the metal used was originally brought into the state of malleable iron, and this was a process of purification, removing the greater part or the whole of the sulphur and phosphorus; and, secondly, it was generally more "dead melted"— the ingots cast from it were more free from honeycomb—than those of the same quality made in other ways.

The Bessemer process, that of blowing air through melted cast iron, produced by far the largest quantity of steel now made. The temperature of the cast iron was raised rapidly, by the combustion of the accompanying silicon, manganese, and carbon; and the blowing was either stopped when steel of the required hardness had been produced, or it was continued until nearly the whole of the carbon had been removed, and carbon and manganese were then restored to the metal by adding spiegeleisen. The former plan was only applicable where the cast iron employed contained so much manganese that 0.1 to 0.3 per cent. remained in the steel, as without that proportion of manganese the metal was not forgeable; and it was thus confined to Sweden and Germany, as few varieties of English, French, or American pig iron contained manganese in sensible quantity. The Bessemer blow lasted from five or six minutes to twenty, thirty, or more, and the heat attained depended on the quickness of the blow, the quantity of metal treated at one time, and its chemical composition. The constituents, whose proportions affected the heat developed, were silicon, manganese, and carbon, more particularly silicon and manganese. The loss of weight in the process varied from 9 per cent. to 15 per cent. or more. The output of a pair of 5-ton converters had been increased, by improvements in the mode of effecting their repair so as to keep them more constantly at work, from six heats in twenty-four hours, or thirty heats producing 150 tons a-week, up to a possible make of forty-five to fifty heats in twenty-four hours, or in a week of ten turns above 1,100 tons of ingots.

The melting of steel on the open-hearth had long been a favorite dream of inventors; but it was not until the regenerative gas furnace gave the ready command of a sufficiently high temperature that any open-hearth steel-making process became a practical success. Two principal types of open-hearth melting furnaces were now in use: the ordinary furnace, with a fixed bed, and the Pernot furnace. The Pernot furnace differed from the common form, in having the bed circular, and arranged so that it might be rotated on an axis inclined at an angle of 5 deg. or 6 deg. to the vertical. The effect of this rotation was that every part of the bed, and all unmelted pieces of steel or iron, were alternately exposed to the full heat of the flame and dipped into the liquid bath.

The open-hearth steel-making processes might be grouped as: (*a*) The Siemens - Martins or scrap processes. (*b*) The Siemens or pig iron process.

In the Siemens - Martin process, as generally carried out, a bath of melted pig iron was first formed on the bed of the furnace, and iron or steel scrap was put into it in successive portions, until a sample taken out and quenched in water was found to be sufficiently soft. From 6 to 9 per cent. of spiegeleisen was then added, and as soon as this was melted, the charge was tapped out. The time taken to work a 5-ton or a 6-ton charge was from nine to eleven hours; 65 tons to 70 tons of ingots per furnace being a fair week's work. The loss was 4 or 5 per cent., and the coal used was 13 cwt. or 14 cwt. per ton of steel made.

In the Siemens process 5 tons of pig iron were charged on the bed of the furnace, and, when melted, iron ore was added until the metal was nearly soft enough for spiegel; 20 cwt. to 24 cwt. of ore were required for a 5-ton charge, and of the metal contained in the ore about one-half passed into steel, so that the yield of ingots and scrap was generally 1 or 2 per cent. more than the weight of pig iron and spiegel put in. The weekly make of a furnace was about the same as in working scrap, and the consumption of coal was 14 cwt. to 15 cwt. per ton.

The working of the Pernot furnace differed in many points from that of the fixed furnace. In melting pig iron and scrap, the pig was first charged over the bed, and the scrap upon it. The fusion was very rapid—five charges, of 4½ tons each, being made in twenty-four hours; and as the coal used was no greater in quantity per day than in a fixed furnace, it was less than half as much per ton. At Allevard, pig iron alone was worked, and a 5-ton charge, with the addition of 7 to 8 per cent. of hammer scale, was brought to the condition of steel in five hours.

Another method of open-hearth steel-making was that of Mr. Blair, of Pittsburg, U. S. A.; the reduction of iron ore to sponge, and the fusion of this on the open-hearth. For localities where charcoal and rich pure ore were at hand, this method seemed likely to have an important future, but it was as yet on trial.

The effect of different proportions of foreign substances on steel was a subject of great importance. The elements whose presence was known to have an influence on the properties of the metal were carbon, silicon and phosphorus, sulphur and manganese, copper, tungsten, and possibly titanium and chromium. The effect of the presence of carbon had long been recognized. The necessity for manganese in steel, to prevent red-shortness, was less generally acknowledged. A common belief was that red-shortness was due, at least in the case of Bessemer steel, to the presence of oxygen. Bessemer steel impregnated with 0.1 per cent. of carbon, or less, no doubt contained oxygen, but it was at the same time free from manganese ; and it was impossible to say to which condition the effect might be due. Harder steel, however, was equally red-short, if it was free from manganese, and there was no reason to believe that snch metal contained oxygen. The percentage of manganese required was dependent on the amount of sulphur in the metal. Steel for rails, with less than 0.04 per cent of sulphur, did not hammer satisfactorily if the proportion of manganese was less than 0.2 per cent.; if it contained 0.08 per cent. of sulphur, it should have at least 0.3 per cent. of manganese; and with as much as 0.12 per cent. of sulphur it would hammer, if it contained not less than 0.4 per cent. There was no evidence that sulphur was removed in any process of steel-making.

The red-shortness of steel, which was diminished or prevented by manganese, must be distinguished from the tendency of the metal to give off bubbles of gas at the moment of setting, so that the ingot was spongy or honeycombed. Both were forms of unsoundness, and either greatly diminished or destroyed the value of the metal; but in other respects they were essentially different. Silicon was capable of replacing carbon, to a great extent, as a hardening element, but the hardness produced by it was coupled with more brittleness than that due to carbon; and its presence, in a proportion exceeding 0.1 and 0.2 per cent. in steel for rails, was looked on as unsafe.

Phosphorus, like silicon, hardened steel and rendered it brittle, but it was much more injurious, and more difficult to remove from the metal, if present in the ore. Malleable iron, practically free from phosphorus, might, however, be obtained from impure pig iron by puddling it thoroughly, and at a high heat, as had been done by Mr. Crampton; or from impure ore by heating it directly in admixture with coal by Dr. Siemens' process. A third mode of obtaining wrought iron free from phosphorus was that of Mr. Henderson—the action of fluor spar on the melted metal in the puddling furnace. The proportion of phosphorus that might be combined with steel, without the latter becoming sensibly brittle, depended on the percentage of carbon and silicon. The best steel contained little or no phosphorus, not more than 0.01 or 0.02 per cent.; but steel containing much more than this might be good enough for ordinary purposes, if the percentage of carbon were diminished as that of phosphorus became greater; until, when the carbon was kept down to 0.16 per cent., steel containing 0.3 per cent. of phosphorus would yet make serviceable rails, and that containing 0.15 per cent. would make excellent tough boiler-plates, which might be bent double when cold, after being heated to redness and quenched in water.* In using materials not very free from sulphur, an amount of at least 0.3 or 0.4 per cent. of manganese was required in the steel to make it forgeable, and this could only be incorporated, without raising the percentage of carbon above 0.15 or 0.18 per cent., by adding ferro-manganese, an alloy of iron, manganese, and carbon, containing 40 to 60 per cent. of manganese. Such an alloy was now regularly manufactured at Terre Noire, and its production at a low price would be the greatest advance in the manufacture of steel that could be looked for, as rendering it possible to make good serviceable steel from inferior materials. The other elements believed to affect the properties of steel were of minor importance.

In making steel rails, there was much difference of opinion on the question, whether it was better to hammer the ingot down into a bloom, or to cog and roll it direct. The objection to cogging was, that the rolls tore the metal, but many engineers maintained that they did not. The difference was probably, to a great extent, due to the varying conditions under which cogging was done. If the cogging rolls were of small diameter and had too much draught, and it was attempted to reduce the ingot too much in size at each pass, the tendency to tear the metal was very great; but if the rolls were large, and the reduction in size attempted in each of the first two or three passes was small, the tendency to tear was slight. The forms of mill generally used for rolling steel rails were the 2-high reversing mill, the English and American arrangements of 3-high mill, the 4-high mill, and Brown's mill. In each, the object was the same, to increase the rapidity of working, so as to get a greater output, and to roll each rail more quickly, that it might not have time to get cool and hard before it was finished. For rolling plates, Lauth's 3-high mill was coming much into use. In this, the middle roll was of small diameter and ran loose, being driven only by the friction of the large roll against which it bore.

The knowledge of the relative properties of varieties of steel of different chemical composition, and of the effect of different modes of treatment, was much less exact than might be supposed from the number of experiments that had been made. The majority of these showed only that a certain bar of metal possessed certain properties. There was rarely an analysis of the steel tested, or a statement of its physical condition.

An interesting point, lately brought forward, was the effect of quenching in water on the very soft steel used for boiler-plates. Plates of this steel were stiffened, and their tensile strength increased, by sudden cooling; but at the same time the metal was much toughened, so that a piece of it treated in this way might be bent up more closely, without cracking, than in its untoughened condition. This result was in harmony with what had long been known, as to the extent to which somewhat harder steel was toughened by cooling it, rather less rapidly, in oil.

An important characteristic of steel was the greater extent to which its strength was diminished, than was that of wrought iron, by notches, holes, or other irregularities of form, causing a sudden variation in the section of a part under strain. This difference was especially important as affecting the strength of steel rails, and the extent to which they were weakened by punching and notching. The present practice was to sacrifice extreme hardness and durability in rails in favor of safety; rails were made of almost the toughest metal obtainable; and when this had been done their strength was reduced to one-tenth or one-twentieth of its normal amount by notches and holes cut in them.

RECENT IMPROVEMENTS IN THE MANUFACTURE OF PEBBLE-POWDER.

NO. 2.

By Major J. P. MORGAN, R.A., Assistant Superintendent, Royal Gunpowder Factory, Waltham Abbey.

" Jourzal of the Royal United Service Institution."

BEFORE closing the work of 1872, I may give the following examples of the firing of mixtures of Waltham Abbey powder to show how satisfactorily the system of mixing has worked.

The hopper described was brought into operation in January, 1872, and the following are some of the mixtures made with it:

Brand.	Stoving.	Density.	No. of Barrels.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
127...	23/1/72	1 .760	51	—	755	1470	18.9	19.2	17.1
	19/2/72	1 .753	127	—	738	1397	16.0	16.0	14.8
	26/2/72	1 .749	62	—	744	1462	19.0	18.2	17.6
		Mean....	......	....	......	1432	17.4	17.3	16.0
No. 127.....	—	—	240	13/3/72	795	1432	17.4	16.7	15.6
136.	2/4/72	1.737	44	12/4/72	905	1461	21.1	20.5	18.5
	3/4/72	1.768	48	12/4/72	906	1396	17.5	17.9	16.2
	4/4/72	1.753	46	12/4/72	907	1432	17.2	16.8	15.8
	8/4/72	1.758	48	12/4/72	911	1452	20.1	19.4	18.9
		Means...	....	....	......	1434	19.0	18.6	17.5
No. 137.....	....	....	186	19/4/72	916	1429	18.6	18.3	17.0
153 ..	10/4/72	1.736	45	19/4/72	913	1465	21.0	20.0	17.9
	29/4/72	1.751	47	10/5/72	929	1464	21.3	20.8	18.6
	15/5/72	1.782	47	23/5/72	976	1403	13.2	12.9	12.4
	16/5/72	1.785	48	23/5/72	977	1405	15.1	14.8	13.9
		Mean....	....	....	.... ..	1434	17.6	17.1	15.7
No. 153.....	....	....	187	6/6/72	1018	1437	17.4	17.6	15.5
224...	29/8/72	1.764	43	13/9/72	11	1514	20.4	18.0	18.0
	31/10/72	1.774	47	8/11/72	108	1433	14.9	15.0	14.9
		Mean....	....	....	.... ..	1471	17.5	16.4	16.3
No. 224.....	....	....	90	13/12/72	164	1472	17-1	16.6	16.9

Brand.	Stoving.	Density.	No. of barrels.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C
225...	31/8/72	1.776	43	13/9/72	13	1539	22.0	20.9	20.0
	1/11/72	1.796	46	8/11/72	109	1416	13.6	13.8	14.2
		Mean....	....	....	......	1480	18.2	17.6	17.3
No. 225.....	... .	... .	89	13/12/72	165	1469	17.9	16.8	17.4

These are some of the results which are calculated to delight the heart of a powder-maker, and prove that a patient continuance in well doing is sure to be rewarded. We may take for granted that not only is the mechanical system of mixing in use at Waltham Abbey a perfect success, but that the method of testing the powder is not only consistent with itself, but calculated to produce one of the prime requisites of good powder, viz., uniformity of results.

A system of mixing powder similar to that just described, is in use at Wetteren, though at first it was not quite so perfect as the plan at Waltham Abbey. At Wetteren, the powder when finished is stored in large bins, and, when a batch of powder has to be made up for shipment, a small portion is taken from each bin for every barrel. Were the bins uniform, this system would be perfect. I believe, of late, attention has been given to insure uniformity of the powder in the bins, somewhat after the plan in Waltham Abbey. The following proofs are given of Wetteren powder:

Lot.	Density.	Moistuie.	Experiment.		M. V.	Pressures.		
			Date.	No.		A.	B.	C.
45	1.773	1.17	7/12/72	151	1427	17.5	15.8	15 1
46	1.766	1.17	"	152	1435	16.7	17.6	16.1
47	1.766	1.17	"	153	1452	17.2	17.0	16.4
48	1.771	1.17	"	154	1440	16.5	16.2	16.1
49	1.771	1.21	"	155	1416	15.6	15.6	15.2
50	1.775	1.13	"	156	1406	14.9	14.3	14.5
51	1.771	1.17	"	157	1438	16.2	17.5	15.3
52	1.773	1.20	"	158	1432	15.8	15.5	15.5

That to produce uniform powder is by no means an easy matter, the proofs of the following lots of pebble supplied by Messrs. John Hall & Son will show:

Lots.	Experiment.		M. V.	Pressures.		
	Date.	No.		A.	B.	C.
1388	7/3/72	785	1414	15.2	15.1	13.8
		787	1442	16.5	17.2	16.3
		790	1481	25.9	21.6	20.5
1399	13/3/72	802	1496	16.5	16.5	15.8
		803	1432	12.3	13.2	13.1
		808	1386	11.2	10.4	11.2

These samples are not given to show any inferiority of manufacture by Messrs. Hall & Son, but simply to illustrate the variations powder is capable of exhibiting, even when the manufacturers may be satisfied as to its uniformity. Messrs. Hall & Son were unfortunate in their first attempts to manufacture pebble, but they afterwards succeeded to a degree that has not left them inferior to any of the other manufacturers. The powder supplied by them, as a rule, exhibits low pressures in comparison with the velocities. Their powder is cut on the principle in use at Waltham Abbey, but the machinery is different. They pass the cakes through the same sort of cutting rollers or through a guillotine machine. In order to convey the cakes from the first to the second cutters, they press each cake between two sheets of canvas. These sheets of canvas hold the strips together after passing the first cutters. The whole cake is in this state turned by hand through a quarter circle and passed through the second pair. This plan is rather more troublesome and expensive than that at Waltham Abbey, but it is equally efficacious.

The Kames Gunpowder Company also at first experienced considerable difficulty in producing good pebble, as the following proofs will show:

Dates of proof, 19th and 20th March, 1872.

Lot.	Samples	Experiment.	M. V.	
71.	1 and 2	846—7	1355	1372
72.	1 and 2	848—9	1367	1359
73.	1 and 2	850—1	1376	1360
76.	1 and 2	844—5	1408	1394
77.	1 and 2	853—4	1403	1389
78.	1 and 2	855—6	1383	1395
79.	1 and 2	857—8	1361	1373
80.	1 and 2	859—60	1365	1378
81.	1 and 2	861—2	1373	1372

The difficulty at Kames this period was to get sufficient velocity, and it was not till after a visit had been paid to Waltham Abbey that they succeeded in mastering the difficulty. In their opinion the powder they afterwards made, and which readily passed the specification, was inferior to that of which the proof has been given; by which I understand that it was not so thoroughly incorporated. I hope further on to give some experiments made at Waltham Abbey, which confirm this opinion.

Messrs. Curtis and Harvey supplied two sorts of powder, one, as I have stated, broken up by the ordinary granulating machine, the other consisting of pressed pellets, afterwards broken in two. The latter powder was found to give very good results when fired, as shown in the following proofs:

Lot.	Experiment.		M. V.	Pressures.		
	Date.	No.		A.	B.	C.
1404	30/11/71	424	1450	15.4	16.4	15.7
		425	1440	16.1	15.7	14.0
		426	1438	13.3	14.3	14.1
1470	15/3/72	823	1422	18.1	17.3	17.2
		824	1424	17.2	17.6	16.7

None of the whole pellets, whether made by the trade or at Waltham Abbey, have ever succeeded in giving results at proof equal to those obtained with pebble, and it seems strange that the simple fact of splitting them in two should have such a beneficial effect. The reason is pretty well understood to be that pressed surfaces are not so readily or regularly inflammable as broken surfaces. The mere fact, therefore, of splitting the pellets furnishes two broken surfaces which the pellets would not otherwise possess.

The following proofs of Curtis' and Harvey's pebble show that though, as a rule, their powder is very uniform, they cannot always supply the same sort:

Lot.	Experiment.		M. V.
	Date.	No.	
1492	16/9/72	17 and 18	1452 and 1467
1493	"	19 and 20	1483 and 1498
1494	"	21 and 22	1502 and 1499
1495	9/10/72	55 and 56	1492 and 1495
1496	17/10/72	76 and 77	1415 and 1408
1497	"	78 and 79	1414 and 1407
1498	"	80 and 81	1466 and 1454

Messrs. Pigou & Wilks had considerable success in meeting the requirements of proof as regards velocity and pressure. The following samples of proof are given:

Lot.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
876	1.758	3/1/72	525	1458	18.3	18.5	15.7
	1.776	"	526	1445	17.1	16.8	15.6
	1.789	"	527	1453	18.4	17.3	15.6
911	1.759	5/3/72	769	1463	19.4	19.6	17.7
	1.782	"	770	1425	14.4	14.4	14.4
	1.763	"	772	1431	17.2	16.4	16.2
934	1.788	12/6/72	1044	1435	16.8	17.0	15.6
	1.774		1045	1446	18.4	18.1	16.7

From what has been said, it will be seen that the manufacture and proof of pebble-powder had very greatly improved during 1872. Density, velocity, and size of grain had all increased, and pressure had materially diminished. The importance of velocity and low pressure need not be explained, but it may be stated that increase of density is an advantage, not only in improving the keeping qualities of the powder, but also in making it pack into smaller bulk, and that increase of size of grain appears to be the best known cause for facilitating the uniform ignition of the whole charge, and thus preventing those wave pressures which occur with smaller grain powder, and which are so very detrimental to the projectiles and powder chambers of the guns. Other things being equal, the larger the grains that can be used, the larger the charges which can be employed with advantage.

It will be noticed also that, instead of the year closing as did 1871, with low velocities, the difficulty is now to keep down the velocity. The beginning of 1873 shows no alteration in this respect, as the following new year's gift will prove:

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
1/1/73	1.781	1.2	72	9/7/73	219	1530	22.4	22.4	21.3

Colonel Younghusband tried some experiments in order, if possible, to bring down the velocity, without leaving an undue amount of moisture in the powder. The first means of doing so that naturally occurs to a powder-maker is to dispense, to some extent, with the most important of all the operations, namely, milling. Four samples of shorter milled powder were accordingly made in different mills and under different circumstances.

They were made from the charcoal then in use, pressed as usual 15¼ inches, and dried 36 hours at 135° Fah. The following is the result of proof:

Stoving	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
3/1/73 A.	1.771	1.08	70	9/1/73	221	1532	24.6	24 0	22.8
" B.	1.761	1.05	70	"	222	1538	25.4	25.1	22 9
" C.	1.768	1.01	76	"	223	1538	25.7	26.0	25.1
" D.	1.759	1.05	66	"	224	1538	24.3	23.2	21.6

It will be observed that the density is low as compared with powder then manufactured, and also that the moisture shows the powder to be dry. The experiment was therefore repeated with powder pressed rather more—15½ inches—and dried 36 hours at 125° Fah.:

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
25/1/73 A_1	1.782	1.08	72	3/2/73	267	1520	21 6	21.6	20.0
" B_1	1.777	1.04	72	"	268	1535	21.8	21.6	20.2
" C_1	1 789	.95	74	"	269	1535	23.3	22.4	21.1
" D_1	1.786	.9	72	"	273	1541	22.1	22.3	20.4

There is some improvement in the pressures, but evidently not much, in the velocity. The experiment was again repeated with charcoal more highly charred, a well-recognized method of reducing the violence of gunpowder. The samples were pressed 15⅝ inches, and stoved as in the last case:

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
8/2/73 A_2	1.759	1.1	78	19/2/73	313	1539	25.5	24.5	22.4
" B_2	1.759	1.08	76	"	314	1533	21.7	21.2	20.7
" C_2	1.759	1.3	78	"	315	1507	19.7	18.5	18.1
" D_2	1.759	.9	76	"	316	1541	24.4	23.3	22.6

Evidently there is no improvement yet, but four other samples were tried made with ordinary charcoal, pressed still more, 15½ inches, and stoved only 24 hours at 125°, with the following results:

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressure.		
				Date.	No.		A.	B.	C.
6/3/73 A_3	1.795	1.26	80	14/3/73	413	1405	14.4	14.3	14.6
" B_3	1.790	1.22	80	"	414	1408	14.2	14.8	12.7
" C_3	1.790	1.30	70	"	415	1393	13.2	13.2	13.0
" D_3	1.788	1.22	74	"	416	1383	11.7	11.6	12.0

I have given these samples at some length, because it was now that I fancied I saw into the secret recesses of pebble-powder and its mode of action. The whole question seems to me to lie in the porosity of the grains. The more porous the grains, the more violent will be the action. It is a case exactly similar to that of large interstices in large charges. If the grains be large it matters little if they be porous, for the pressure of the gas in the powder-chamber will force the flame into the very heart of the grains, and hence the very violent action of $2A_4$ powder. Now, it follows that anything which adds to, or takes from, the porosity of the grains during manufacture will have a corresponding effect at proof. It was to me a very remarkable fact that as summer advanced the tendency both with large and small-grain powders was for the density to increase. The presses had to be continually altered so as to press less and less in order to give the required density. No doubt this is due to the fact that the incorporating or milling is more perfect in summer than in winter, a fact well known to manufacturers.

The more milling the powder receives, the more pasty it becomes, so much so that with fine-grain powder, where long milling is used, the powder on the beds of the mills has a tendency to adhere to the runners. This pastiness has the effect of rendering the powder more compact and easily pressed. The opposite effect, of course, takes place with shorter milled powder. It will not press so close together, and will be less dense and more porous than the powder longer milled. This accounts for the low densities of the 3/1/73 samples. It also accounts for their more than usual dryness, for, if the powder be porous, the more readily will it part with its moisture.

The same remark applies to 25/1/73 samples, for evidently both sets have been dried sufficiently, and part of the moisture is to be regarded as what the powder has re-absorbed after stoving. The 3/1/73 samples being less dense, though they have been more dried at first, may, at the time of being tested for moisture, have absorbed more moisture than the 25/1/73 samples which are denser. The amount of moisture, however, in powder gives very little idea of what may be expected at proof. This I had long known, and a very short inspection of the samples already given, will show that this is the case. The reason of this, however, was now plain to me; for evidently the powder must dry from the surface to the centre, and probably in the centre of each grain there is a considerable portion which receives little drying. The average amount of moisture will therefore be determined by the amount of moisture which was in the powder before stoving, and will give but little idea of the amount of dryness of the outer portions of the pebbles, which have the most important effects on the proof.

The 8/2/73 samples admit of ready explanation on the same principles. Though more pressed, the density is again lower. The grains of charcoal, being harder, will still more refuse to incorporate, and will make the powder more brittle and less pasty, which wlll manifest itself in the density at pressing.

The 6/3/73 samples show the old tendency to low velocities. Comparing, however, these samples with powder made at the same period in 1871 and 1872, which was dried the same amount, it appears that the densities then were less, and consequently the rule still holds good.

With fine-grain powder, long milling and slack-burned charcoal increase the velocity obtained at proof, but with pebble the reverse holds good, and here we have an exact parallel to the case of fine-grain and large-grain powder in large charges. With fine-grain powder in small charges, the charcoal probably has not time to seek its oxygen unless it be brought very intimately in contact with it; but in large charges, where the time of explosion is necessarily much longer, owing to the great resistance of the shot, time is not so great an object, and the great heat may release the oxygen much more effectually and rapidly. It is probable also that each small particle of charcoal may require a certain time to burn, and there may be ample time in large charges, but not in small charges, unless the particles are pulverized considerably by long milling. It is well known that a "mixed charge" will only just flare up if fired in a small quantity, but if it be fired in bulk the result is an explosion. This explains the observation I made with regard to the Kames pebble, for, if that firm over-milled their powder with the idea of getting up the velocity, from the observations I have made, it will be seen that it would produce the opposite effect.

Another observation may be made with regard to the manufacture of pebble-powder bearing on the same point. Powder when incorporated in the mills usually has a certain percentage of moisture in the charge with a view of aiding the incorporation. Fine-grain powder is usually worked with about 3 per cent. of moisture, but pebble with from 3½ to 6 per cent. An explosion of fine-grain powder with 3 per cent. of moisture is very violent, and generally destroys the building; but, with pebble-powder and 5 or 6 per cent. of moisture, the explosion does little or no damage.

It is, therefore, a great advantage to work with as much moisture as possible. Some have thought that the more moisture in the powder when milled and pressed, the more moderate will be the results of proof, and that this is due to a sort of hard and crystalline texture which the powder thus assumes. I do not believe in this theory, and certainly the results of proof do not bear it out. It is true, no doubt, that powder if too dry will not pack well together, even if pressed with a very high pressure, and this was found to be the case in the earlier experiments to obtain powder for heavy guns, when the Doremus pellets, which were pressed with as much as three tons to the inch, were found to be very violent even in field guns. A certain amount of moisture must therefore be in the powder when milled and pressed, in order to make it pack together; but if this amount is exceeded, the results are prejudicial, and, with pebble-powder, instead of mitigating the violence, rather increase it. No doubt, if the powder be not properly dried, the moisture has a moderating tendency, and I think this is the reason which has given rise to the crystalline theory. If, however, the powder be thoroughly dried, it has always been found that with moisture over a certain percentage—about 4½ or 5 per cent.—it is much more difficult to get a high density. I think this and the more violent action at proof are caused by the moisture in forcing its way from the interior of the pebbles, forming porous channels, which not only swell the powder, but also leave passages for the flame to penetrate more readily into the interior. If too much moisture be in the powder when pressed, the water can be seen to be squeezed out, showing that the extra amount can produce no good effects, and must, if confined, prevent a high density being obtained.

The great difficulty of getting the moisture from the interior of the pebbles, as has been stated, is another reason why too much moisture should not be used. In making these observations, however, I should observe that they are entirely my own views, and are not necessarily accepted by every one.

I may, however, make a remark to which all I have said seems naturally to tend, namely, that to produce a powder, which shall be moderate in its action, is both troublesome and expensive, unless an undue amount of moisture be admitted, but a powder can be produced, safely, expeditiously, and economically, which, though somewhat violent in its action, does not give an exceptionally high pressure in comparison with the velocity. If the guns will stand, no difficulty will be found in providing a powder capable of giving the very best results.

The manufacture of pebble has been carried on in 1873 much in the same manner. The variations of the seasons have to be studied, and, as a rule, it has been found that density is more easily obtained in summer than in winter, owing to the more effectual incorporation. The amount of milling has been reduced, as it appears unnecessary to prolong this operation, which is the most dangerous of all, more than is absolutely necessary.

The press-boxes at Waltham Abbey produce cakes of powder 30 inches square, which are not only too large to pass through the pebble machine, but the size of the copper plates between the cakes allows the plates to buckle and so produces cakes of uneven thickness. The perfect action of the machine depends to a great extent on the uniform thickness of the cakes, otherwise the long strips are broken up into short pieces. A plan of remedying this defect suggested by the Assistant Chief Foreman of machinery was carried out during 1873. It consists in dividing the press-box and block into two, so that the cakes produced are only of half the width and suitable at once to pass through the pebble machine without being broken up.

Care, however, must be taken after the cakes are pressed to keep them from buckling, which they will readily do when first pressed.

A large amount of L. G. powder has been re-worked during the year. The following are the first proofs of this powder which was made from Curtis's and Harvey's L. G. powder. The drying was 38 hours at 127° Fah.

Stoving.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
14/7/73	1.806	1.27	74	29/7/73	682	1415	13.5	13.2	13.8
15/7/73	1.803	1.48	74	,,	683	1409	13.2	12.9	13.0
17/7/73	1.803	1.28	76	,,	684	1356	11.6	11.2	10.3
18/7/73	1.804	1.41	—	,,	685	1419	13.2	13.2	13.3

These stovings were mixed and redried and again proved.

Experiment.		M. V.	Pressures.		
Date.	No.		A.	B.	C.
15/8/73	697	1454	14.4	14.7	14.2

This is most excellent powder, and it will be observed that the density is high and the powder consequently difficult to dry. The following are proofs of pebble re-worked from Hall & Son's L. G.:

Stoving.	Density.	Moisture.	No. of pebbles.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
28/11/73	1.789	1.20	76	8/12/73	785	1432	14.8	15.0	14.6
1/12/73	1.797	1.11	76						
9/12/73	1.792	1.37	76						
10/12/73	1.796	1.07	82	15/12/73	790	1454	15.9	15.6	15.1

These stovings were dried 36 hours at 127°.

At this time, and for some months previously, it has been the *rule* to prove double stovings instead of proving each separately, and this is attended with no inconvenience; for, even if a double stoving fails, there is still opportunity in the four-way hopper of mixing it with another double stoving of an opposite character.

It will be seen that the question of stoving is a very important one. What is required is to give the powder that amount of stoving which will leave it in a normal condition as regards moisture, so that afterwards the velocity shall not be affected. In order to obtain some data on this point, 10 barrels were dried 72 hours at 125° Fah. and fired once a month.

Stoving.	Density.	Moisture.	Experiment.		M. V.	Pressures.			Corrected.			
									M. V.	Pressures.		
			Date.	No.		A.	B.	C.		A.	B.	C.
31/5/72	1.773	77	12/6/72	1038	1502	20.4	19.8	18.8	—	—	—	—
"	"	—	12/7/72	1107	1490	19.3	19.5	18.6	—	—	—	—
"	"	—	7/8/72	1157	1473	19.3	18.4	16.5	—	—	—	—
"	"	—	13/9/72	7	1515	22.6	22.4	19.4	—	—	—	—
"	"	—	9/10/72	57	1520	20.4	19.0	18.9	1523	20.4	19.0	18.9
"	"	1.28	18/11/72	121	1501	18.2	18.2	17.1	1507	18.3	18.3	17.2
"	"	1.17	13/12/72	166	1499	19.4	19.2	17.4	1507	19.5	19.3	17.5
"	"	1.33	9/1/73	225	1511	19.5	20.0	19.3	1522	19.7	20.2	19.5
"	"	1.38	10/2/73	297	1486	17.9	17.5	17.8	1501	18.2	17.8	18.1
"	"	1.35	12/3/73	398	1486	19.3	18.3	17.4	1506	19.7	18.7	17.8
"	"	1.30	10/4/73	501	1474	16.8	16.6	16.5	1499	17.3	17.1	17.0
"	"	1.16	14/5/73	544	1495	18.3	18.9	17.8	1522	18.8	19.4	18.3
"	"	1.3	19/6/72	603	1493	19.8	19.7	18.2	1523	20.4	20.3	18.8
"	"	.95	15/7/73	657	1485	18.9	18.5	17.5	1518	19.5	19.1	18.1
"	"	1.11	15/8/73	698	1485	21.1	20.5	18.6	1520	21.8	21.2	19.3
"	"	1.21	19/9/73	732	1458	18.5	17.9	17.0	1495	19.2	18.6	17.7
"	"	1.44	17/10/73	746	1476	17.5	17.9	17.0	1513	18.2	18.6	17.7
"	"	1.41	14/11/73	769	1452	16.6	16.3	15.4	1490	17.3	17.0	16.1
"	"	1.34	15/12/73	788	1470	17.8	17.2	15.9	1509	18.6	18.0	16.7
"	"	1.18	12/1/74	801	1483	18.1	17.9	16.3	1523	18.9	18.7	17.1
"	"	1.20	13/2/74	106	1507	18.1	18.9	18.3	1512	18.2	19.0	18.4
"	"	1.15	20/3/74	847	1426	15.3	14.7	15.1	1468	16.1	15.5	15.9
"	"	1.0	20/4/74	875	1456	18.0	17.1	17.0	1500	18.8	17.9	17.8
"	"	—	21/5/74	144	1495	20.3	19.5	19.3	1502	20.4	19.6	19.4

It will be observed in the additional columns for velocities and pressures, that corrections have been made for the wear of the bore of the proof gun. These were obtained by firing identical samples from two proof guns, one new and the other worn.

Stovings.	Density.	Moisture.	Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
9/8/73	1.777	.94	80	21/8/73	706	1498	20.3	20.3	17.7
					4	1537	20.6	20.3	18.7
11/8/73	1.787	.99	70	"	707	1467	18.1	17.8	17.5
					5	1508	19.1	18.4	17.5
12/8/73	1.787	1.14	74	"	708	1459	16.5	16.5	16.1
					6	1486	17.0	16.9	16.7
21/8/73	1.799	.99	64	3/9/73	726	1433	16.0	15.7	14.6
					16	1470	17.6	16.6	16.4
27/8/73	1.785	1.11	64	"	727	1441	14.9	14.8	15.7
					17	1478	16.5	16.5	16.5
23, 25/8/73	1.793	1.04	66	"	725	1434	15.1	14.4	13.6
					15	1470	15.8	16.1	15.0
24, 25/2/74	1.808	1.41	77	9/3/74	825	1419	16.4	16.1	15.5
					110	1450	16.8	15.9	16.5
25, 27/2/74	1.804	1.37	78	"	826	1399	17.4	16.5	14.8
					111	1439	16.6	16.3	15.2
26, 27/2/74	1.779	1.05	77	"	827	1484	22.3	22.1	20.2
					112	1535	22.8	23.1	21.9

From these experiments it is concluded that about 5 feet must be added for 100 rounds to reduce the velocity to that of a new gun, and about 2 cwts. for each 100 rounds for pressure. The corrections are not shown in the old gun in use in 1872, as that gun as a rule fired much less violent powder, and the corrections would probably be $\frac{1}{3}$ less. If we neglect the sample fired 13/9/72, where the pressures are evidently exceptionally high, it will be observed that the powder at first loses in velocity and pressure from its having been overdried, but that afterwards it does not materially lose its velocity or pressure when it once has reached a normal state of moisture, as it may be supposed to have done in November, 1872.

Some experiments have lately been made by Colonel Younghusband as to the time required to dry powder of large size of grain. The samples chosen were inch cubes, and the specimens were dried whole and compared with similar specimens broken up to a size rather larger than R. L. G. with the following result:

No. of hours dried at 160° Fah.	Loss of moisture in inch cubes.						
	Waltham Abbey.		Hall and Son.				
	Density 1.792.		Density 1.82.				Density 1.75
			A		B		C
	Whole.	Broken up.	Whole.	Broken up.	Whole.	Broken up.	Whole.
24	.284	1.103	.237	1.062	.290	1 312	.308
48	.464	1.103	.402	1.194	.501	1.527	.484
72	.490	1.103	.568	1.261	.712	1.527	.625
96	.594	1.103	.663	1.261	.817	1.527	.659
120	.619	1.103	.710	1.261	897	1.527	.659
144	.645	1.103	.805	1.261	.976	1.527	.681
168	.697	1.103	.876	1.261	1.108	1.527	.703
192	.800	1.103	.947	1.261	1.134	1.527	.703
216	.800	1.103	.971	1.261	1.213	1.527	.703

The question of the best method of drying powder has received some attention of late at Waltham Abbey, and, in order to gain some information to aid in the construction of a new stove, an experimental stove was built of 8 feet square internal floor and about 10 feet high. Colonel Younghusband wished to have the hot air pass from above downwards, as that is evidently the best method of drying, and is used in some places where drying is carried on, as at Enfield Lock, for drying wooden stocks. In the stoves in ordinary use at Waltham Abbey it is found that the powder sweats very much during the first 10 or 12 hours, and evidently that there is not sufficient circulation to carry off the moisture. The hot moist air seems at first to rise and get heavy with moisture and then come down again to the bottom of the stove, circulating only in the stove itself.

But if the hot air come in at the top and descend it has no tendency to rise again as it absorbs moisture, cools, and becomes heavy. Evidently also pebble-powder gives special facilities for drying, as the large interestices give facilities for making the current of heated air pass through the powder.

The plan adopted therefore was to make the current pass down through a thick layer of the powder, which for this purpose was placed in bins. No other passage was allowed for the air.

The pipes were placed underneath the stove. The object of this is to insure circulation. Hot air tends always to rise as water tends to fall. But as water will always when confined in any case rise to its original level, so I conceived hot air, when confined to a passage, will always force its way down to its own level. If an outlet therefore be allowed for the hot air from the bottom of the stove a continual current ought to be established. The outlet, however, was led into a flue so as further to increase the draught.

For some reason or other a sufficient current was not established until the flue was increased by a wooden continuation, but when this was added it was found, when at work, that the draught was sufficient to draw so great a quantity of air through the stove as to bring down the temperature. The temperature could be raised by the diminishing the opening by which the external air was admitted to the steam pipes to become heated. The best plan would be to bring the outlet into communication with some arrangement which would produce a partial vacuum, such as a steam jet; for a vacuum is a well known method of drying. Thus the temperature might be lowered in the stove with advantage to the drying of the powder, a low temperature and sufficient current of air being the best plan of drying.

I may conclude this paper by giving a few samples of powder fired in the 35-ton gun, by the way of experiment, to see what powder is likely to be most suitable. All the rounds were fired with 110 lbs. of powder and 700 lbs. of projectile. (*See table next page.*)

These are some very remarkable results, which, doubtless, are all capable of explanation, but require a more accurate knowledge of the whole curves of pressure for their complete elucidation than the mere maximum pressures are capable of furnishing. For the present, however, they must be left in the hands of the Committee on Explosives, with the remark that, true to themselves in their apparent inconsistencies, these samples in many cases seem to arrange themselves in exactly the opposite order to what might have been expected. One observation, however, I may make, the truth or error of which time and further experience may possibly determine. The effect of size of grain is well known, and the theory of each grain burning from surface to centre has often been advanced, and therefore calls for no special remark. It should, however, also be understood that with this theory must be combined a consideration not only of the density but also of the varying porosity of powder, which allows each grain to burn more or less rapidly according as the density is less or more, and more or less unevenly according to the number and size of the pores.

Porosity and density, though intimately allied, are not necessarily identical, and this helps to a great extent to explain some of the apparent anomalies.

Powder of a density greater than 1.82 or 1.84 *does* burn uniformly; and Capt. Castan says that such powder when picked up unconsumed, after having been fired from guns, shows none of the pit

Description of powder.	Density.	Fired in 35-ton gun.			Fired in 8-inch gun.				
		Muzzle. velocity.	Pressures.		No. of round.	Muzzle velocity.	Pressures.		
			A.	C.			A.	B.	C.
W.A. pebble, 22/4/73	1.79	1345	23.2	16.6	556	1468	17.9	17.1	16.7
" inch cubes, 23/4/73	1.79	1328	21.8	19.2	564	1431	18.2	17.3	16.4
" lot, 1970.................	1.78	1359	23.4	20.7	618	1486	19.5	19.7	18.5
" inch cubes...	1.82	926	2.5	broke	800	750	—	—	—
" " "	1.77	not fired			94	1535	21.7	20 5	18.8
" " "	1.75	1352	24.1	19.6	104	1485	17.0	17.3	15.7
" " "	1.73	1368	24.8	22.3	105	1504	18.4	18.8	18.1
" 1¼-inch cubes	1.77	1334	20.7	18.5	95	1469	15.7	15.0	15.5
" " "	1.75	1311	24.1	16.0	96	1425	13.2	13.2	12.6
" " "	1.73	1334	22.5	19.4	98	1456	14.6	14.7	14.2
" 2-inch cubes............	1.79	1095	7.5	6.8	—	—	—	—	—
" " "	1.77	1262	18.0	15.1	99	1429	13.5	13.9	—
" " "	1.75	1239	13.4	11.3	100	1367	9.9	9.9	10.2
" " "	1.73	1241	13.6	11.7	101	1371	10.8	10.6	10.8
H. and S. inch cubes, A........	1.82	1355	19.8	18.2	736	1440	12.8	12.9	13.3
" " B........	1.82	1376	24.0	22 4	738	1480	11.3	11.7	11.5
" " C........	1.75	1385	23.8	19.8	1192	1483	17.7	18.6	18.2

marks which are to be found with powders of less density. These pit marks are doubtless due to the penetration of the flame into the porous channels in the grains, which allow the flame to enter further into the interior than would otherwise be the case, and thus accelerate the combustion. The effect of porosity, however, is mitigated by the amount of moisture the powder may contain, and which, for some cause or other, seems to have an effect on the rapidity of combustion much greater than would be anticipated. Possibly it may generate steam of a tension sufficient to counteract the pressure of the flame. It is not, however, the actual amount of the moisture that affects the rate of combustion so much as the position it occupies. Moisture in the interior of a grain affects the combustion but slightly, but moisture in the exterior moderates considerably the rate of combustion at the period when the effects of greatest importance are produced.

Waltham Abbey inch cubes of high density were thoroughly dried, and the mild character of the sample, 1.82, is to be regarded as entirely due to the high density. It is not to be compared with Messrs. Hall & Son's sample of the same density, which was made with a different charcoal, viz., dogwood, instead of alder. Some of the discrepancies obtained with the other samples, however, are not so easily explained, but it is probable that the reason why in some cases the lower densities gave more moderate results than the higher may be that the lower densities may have allowed the moisture to penetrate by absorption further into the pebbles.

Correct inferences cannot be drawn till the whole grain has reached its normal state of moisture, and only thus can the relative effects of size of grain and density be fully determined. This manifestly must be a work of considerable time. It is worthy of remark, however, that lot 1970, which is a violent service pebble set apart for the proof of guns, does not appear to be much behind even the very best of the samples, if we have regard to a comparison of velocity and pressure. An increase of the size of the charge with some of the more moderate specimens, may, however, determine in favor of some of the milder powders for our heaviest guns.

REPORTS OF ENGINEERING SOCIETIES.

The New York Society of Practical Engineering. This society is working with renewed vigor, having adopted, with the current year, the plan of holding quarterly series of lectures, each including several successive meetings. The first session commenced Monday evening, June 19. The meetings were held in the Geographical Rooms, Cooper Institute, the President, James A. Whitney, M.E., in the chair. The lectures and papers of the first session were as follows: Tuesday evening, January 19, Hon. Wm. J. McAlpine, on "The History of Engineering Thought;" January 20, Dr. P. H. Van der Weyde, on the "Dykes and Dams of Holland;" January 21, closing address, first session, on "Steam-Boiler Explosions," by the President. The second session comprised a lecture on Monday evening, January 25, on "Transmission of Power by Belts," by John W. Sutton, M.E.; January 26, "Construction of Lighthouses," by C. B. Boyle, C. E.; and January 28, miscellaneous papers, which comprised "Removal of Snow from Streets by Melting," by W. M. Edwards; "Electricity for Railway Signals," by Prof. Wm. Robinson; and "Safety-Armor for Firemen, Miners, etc.," by J. H. Beardsley, Esq.

The second quarterly series embraced a single session, commeneed on the evening of April 19, and included a lecture on "Steam-plowing," by D. D. Williamson, M.E.; April 20, on "Sanitary Engineering," by W. H. Moore, C. E.; April 21, by Lemuel W. Wright, M.E., on the "Construction of Ordnance;" and on April 22, by George Ed. Harding, C.E., on the "History of Iron Manufacture," this closing meeting of the session also including an extemporaneous address by Hon. Abram S. Hewitt, M.C., on the latest Improvements in the Manufacture of Iron and Steel. The midsummer series of lectures are expected to exceed in number either of those hitherto held, and to be of unusual interest.

American Society of Civil Engineers. The society has become fully settled in the new rooms corner of Broadway and Twenty-third street.

Preparations are in progress for the annual convention, to be held in Pittsburgh, on the 8th, 9th and 10th of June.

The list of topics which may be discussed at the convention, together with the titles of papers presented since the last convention, are given below.

1. Bridges.—*A.* Arched Bridges: XCVIII. Upright Arched Bridges, J. B. Eads, October and following. *B.* Draw Bridges: XCII. Draw Spans and their Turn Tables, C. S. Smith, August. CV. Principles of Construction of, and Calculation of Strains in revolving Draw Bridges, C. Herschel, March. XCVII. Utica Lift Draw Bridge, S. Whipple, September. *C.* Foundations: LXXXIV. Replacing a Stone Pier on a Pile Foundation, J. A. Monroe, June. XCIII. Foundations for Brooklyn Anchorage, East River Bridge, F. Collingwood, August. *D.* Erection of Structures: XCIX. Notes on the Erection of Illinois & St.

Louis Bridge, T. Cooper, November. *E.* Bridge Accidents: Reports on the Means of Averting Bridge Accidents, submitted March 3d, 1875, J. B. Eads, Chairman of Committee, May (1875).

2. Steam Engines and Furnaces.—*A.* Pumping Engines: Report on Comparative Examination of the principal of Pumping Engines in Use, G. P. Low, Jr., Chairman of Committee, May (1875). *B.* Compound Engines: CIV. Compound and Non-Compound Engines, Steam Jackets, &c:, C. E. Emery, February. *C.* Furnaces: CII. Efficiency of Furnaces burning Wet Fuel, R. H. Thurston, December, January.

3. Railroads.—*A.* Rails: LXXXVIII. Report on the Form, Weight Manufacture and Life of Rails, A. Welch, Chairman of Committee, July, May (1875). Memoirs on Rails, A. Welch, July. LXXXIX. Weight of Rails and Breaking of Iron Rails, O. Chanute, August. *B.* Railway Signals: Report on Railway Signals, J. D. Steele, Chairman of Committee, May, (1875). *C.* Rapid Transit in Large Cities: CVI. Rapid Transit and Terminal Freight Facilities, O. Chanute, M. N. Forney, A. Welch, C. K. Graham, F. Collingwood, Part I., March. *D.* Cheap Freight Transportation: CVI. Rapid Transit and Terminal Freight Facilities (the same), Part II., March. *E.* Railways Systems Contrasted: LXXXV. European Railways, as they appear to an American Engineer, W. H. White, June.

Boston Society of Civil Engineers.—The annual meeting was held at the Society-rooms, 66 State Street, Boston, March 24th, 1875—President Thomas Doane in the chair and twenty-six members present. The regular business was transacted, including the reading of the Annual Report of the Government by the President, and the election of officers and members. The Report of the Government embraced a short history of the Society from its formation in 1848 to its re-organization during the last two years, and included reports of the President, Treasurer, and Librarian, which showed the Society to be in good condition, with a large list of members, and a healthy financial exhibit. The officers elected for the ensuing year are as follows:

President, Thomas Doane; Vice-President, Desmond FitzGerald; Secretary, George S. Rice; Treasurer, Clemens Herschel; Librarian, Edward K. Clark; Auditor, Joseph P. Davis.

A statement of some facts and experiences on heated air as a motive power developed by some experiments in late years was made by Mr. Chas. H. Parker, of Boston. Mr. Parker commenced with the mechanical properties of heated air, and stated that the first engine was built in Scotland, in which the products of combustion entered with the air, and failed on account of the large particles of fuel entering the cylinders. Foremost amongst the obstacles to overcome when he commenced the experiments, was the discovery of a lubricator and a method of keeping the valves cool, which he virtually accomplished, by the use respectively of powdered plumbago and a refrigerating process, in a machine which he exhibited at the Paris Exposition, with two twenty-inch cylinders and of twenty-three indicated horse power. Mr. Parker spoke of Erricson's valuable experiments and of his results, and said that with the exception of these experiments the majority of investigations made in this country had not been for science, but for the purpose of making money, engines having been shoved upon the market before they were perfected.

The advantages of heated air as a motive power were the independence of water, having the medium always around you; the employment of light metals and less tonnage for sea vessels. Among the objections are the complicated machinery, the difficulty in starting and feeding, which was necessarily done through a double feed box.

Mr. Parker thought he saw the reasons why it would succeed, and if an engineer would conduct experiments on scientific principles, there would be good results. After some discussion the Society adjourned till the next regular meeting in April.

IRON AND STEEL NOTES.

A CORRECTION.—The article on the "Bessemer and Siemens-Martin Steel" in our May issue should have been credited to the *American Manufacturer and Iron World.* It appeared as an editorial in the columns of that valuable paper some three months ago, and was regarded of sufficient value to be widely appropriated on the other side of the ocean, where its ownership was speedily forgotten. In the plenitude of our *eclecticism* we culled it as rather a choice bit of foreign scientific literature, and credited it vaguely in common with the *Bulletin*, to a "foreign contemporary."

RUSSIAN METALLURGY.—The increase in the metallurgical establishments is still being warmly fostered and pushed on by the Government. Two new large establishments have just been added to those of the south—an iron foundry and an iron mine. The foundry is placed under the charge of an Englishman, John Youse, by the Government. The mine is a private enterprise, for which the funds have been provided by the iron-merchant, Pastuchoff. The two establishments have cost large sums of money, but seem to be in full tide of prosperity. This prosperity is almost an inevitable consequence from the exceptional richness of the iron ores and coal beds of the basins of the Don. Attention to this fact is said to have been first drawn in 1837 by M. Le Play, Director of L'Ecole des Mines, and chief of the Demidoff expedition. Prince Woronzoff was the first to commence working these rich deposits and afterwards the Duc de Liwen leased a large area to a company. The best iron ore found there is an oxide containing 45 per cent. of iron. A daily quantity of 1,200 to 1,500 tons of coal is now produced there. From January 1st to July 1st, 1874, the production amounted to 114,000 tons of coal, 17,280 tons of minerals, and 13,740 tons of pig-iron were run, and 10,200 tons of bar iron were manufactured.—*Iron.*

PHOSPHURETTED STEEL.—A year or two ago, it was generally admitted that a pure ore or pig-iron, and especially one containing less than 0.03 to 0.05 of phosphorus, was absolutely essential to the production of a good Bessemer steel; the consequence has been that many of our richest iron ores, most chiefly mined and supplied, have been ruled out as unfit for Bessemer work. Such are most, if not all, of the limonite and fossiliferous ores of Pennsylvania, Virginia, Tennessee, Georgia, and Alabama, in which the percentage of phosphoric acid runs usually from 0.05 to 0.15 per cent., corresponding to about double these amounts in the pig-iron. This small percentage of phosphorus has been a perfect bugbear to iron manufacturers, and so important was it considered that one of our large steel works imported 10,000 tons of ore from Algiers at a cost of about $16 per ton, because it was, at that time, impossible to secure ores here sufficiently free from phosphorus for use in the manufacture of steel rails. Innumerable efforts have been made to get rid of the phosphorus in the several processes through which the iron passes in its manufacture, but these efforts have been but partially successful, and then only in the puddling process, and, consequently, of no use in the manufacture of Bessemer steel.

Investigations which have been made during the past two or three years have developed the fact that by a kind of homœopathic treatment (*similia similibus curantur*) certain substances which themselves give hardness and brittleness to steel may be in part substituted for other ingredients having a similar tendency, to the great improvement of the resulting metal. It has thus been found that by securing proper relative proportions of carbon, phosphorus, silicon, and manganese, a steel of great softness and strength can be obtained, while the same percentage of phosphorus in ordinary steel would have indicated very different properties.

There is no longer much doubt of the fact that manganese exerts upon steel a body-giving and toughening influence as well as a neutralizing effect on the hardening or cold shortening due to phosphorus. Though these properties of manganese have been blindly suspected for some time, the mutual dependence and, to a certain extent, interchangability of carbon and phosphorus were not fully appreciated till the success of M. Tes-ie du Motay in producing with ferro-manganese a good rail steel containing about .12 carbon, .25 phosphorus, and .75 manganese, was fully established.

The secret of success appears to be putting into the metal from $\frac{3}{4}$ to 1 per cent. of manganese without bringing the percentage of carbon above .16, while the metal contains the ordinary amounts of phosphorus and silicon, or, say, .25 to .29 of the former and .3 of the latter. When the percentage of phosphorus is diminished that of carbon should be increased, and *vice versa* within certain limits. We have published, vol. XIX. p. 36 and p. 68 of this journal, a description of the process of manufacture of both rail and plate steel by the use of ferro-manganese, and of tests applied and sustained by the product at the Terre Noir Works. It is not necessary to repeat these, but the importance of the subject to our ironmasters justifies a further reference to the successful use of ferro-manganese containing about 50 per cent. of manganese in the manufacture of these soft steels. Steel is undoubtedly destined to supplant iron for almost every use where the latter is now adopted. It is of the utmost importance that our ironmasters should seek out and apply those improvements in its manufacture, that will enable them to make use of our unrivalled advantages in the abundance and cheapness of our iron ores and fuels, and thus place us in a position to compete successfully in other markets than our own.—*Engineering and Mining Journal.*

RAILWAY NOTES.

From the *Monituer Industriel Belge* we learn that the Prussian railway authorities are busily engaged in the construction and re-construction of their rolling stock. The number of engines and carriages made during the past year and to be made during the present are 1,549 locomotives, 1,670 passenger carriages, and 17,000 good trucks of all kinds, to the value of 201,000,000f.

A trial of a locomotive for mountain railways, constructed by the *Societe Internationale des Chemins de Fer de Montagnes* at Aaram, was made a few days since on the Rigi Railway, on a distance of 2 kilometres, with a gradient of 17 per cent. (or nearly 1 in 6.) The trial was most successful, and reflects much credit on Herr Riggenbach, the engineer of the Rigi Railway, by whom this engine was designed.—*The Engineer.*

The *Journal des Debats* gives the following particulars respecting the workings of the French railways during the past year: During 1874, the total length of the lines of railway in France was increased from 18,563 kilometres —11,509 miles—to 19,110 kilometres—11,848 miles. The total receipts amounted to 797,-365,349f. The average receipts per kilometre, which, 1873, was 44,152f., diminished in the following year to 42,517f., showing a difference of 1,635f., or a falling off of 3.70 per cent.

The promoters of the proposed railway from Palermo to Trapani have entered into arrangements with Messrs. Clark, Punchard & Co. for the construction of that line, and a representative of that firm, Mr. William Major, has already arrived in Sicily to examine the ground previous to signing the definite contract. This line is a most important one for the welfare of the island, as the western portion, up to the present time, is entirely unprovided with railway communication.—*The Engineer.*

Perhaps the heaviest piece of main line traffic in the world is that on the London and North-Western Railway between London (Euston station) and Rugby—a section 83 miles long. On this section the following trains run through: 30 express mail trains at 40 miles an hour; 5 at 36 miles an hour; 29 passenger trains at lower speeds and stopping at all stations; 32 express goods trains at 20 to 25 miles an hour; 27 ordinary goods trains, and 23 local goods and mineral trains—a total of 64 passenger and 82 freight trains in 24 hours.—*The Engineer.*

ENGINEERING STRUCTURES.

The utilization of the sewage of Paris on the plains of Gennevilliers, containing an area of 800 acres of light sandy soil, is now being practically carried out. A large sewer is now being constructed to carry away the sewage from the main sewer at Clichy-sur-Seine. The new sewer will be 1.60 metre internal diameter, and 3,750 metres in length, and when completed half the sewage of Paris will be utilized.

The "Iron Gates" of the Danube.—To avoid the rocks by which the navigation of the Danube has for ages been obstructed at this point, the Government engineers had prepared a new bed for the river, which was to have been turned into it in the usual ceremonial fashion on the 15th of next month. The Danube, however, has virtually anticipated the ceremony by taking possession in its own way, of its new bed.

This river was dug out in three sections, separated from each other by two dykes, which were left, and over which the roads led to the old bed. The embankment had been raised all along the line and partially reveted with stone, but there remained still a good deal of the stone reveting to do between the two dykes. In order to do this more cheaply and expeditiously it was determined to make an opening in the upper dyke, so as to allow the stone barges to pass through. The news excited some misgivings, and there were warning voices which predicted that the lower dyke would scarcely be able to resist the pressure of the water; but the engineers were confident in their power of regulating the inflow of the stream and to stop up the gap if necessary. Events proved that they had been too confident, for scarcely was the channel opened when the stream rushed in, widening the gap soon from 12 to 100 feet, carrying away the bridge which had been constructed. The dyke being in an oblique direction the gap was made towards the right bank, the consequence of which was that the force of the stream rushed in that direction, carrying away the masonry and stone revetment for a considerable distance. In less than twelve hours the basin filled, and the current seemed to have stopped, but the workmen had scarcely retired to rest when the news came that it had set in again, indicated that the water had made its way through the lower dyke. In order to obviate further mishap to the embankment, which would have followed had the river broken through, an opening was made in the centre of the dyke when the same thing occurred as at the upper dyke, the water rushing through and carrying away the dyke right and left, without doing any further mischief to the embankments.

Curiously enough, the difference in the level of the old channel is not so great as might have been expected, 18 inches being registered as the fall, and for the present there are two main streams, the old one not having been as yet stopped, by sinking stone barges, &c.

ORDNANCE AND NAVAL.

A New Lifeboat.—There has just been exhibited to the brethren of the Hull Trinity-house, and to the principal ship owners of the port, a new patent lifeboat, patented by Messrs. Anderson and Burkinshaw, of Burlington Quay, and it is by them termed the "Reversible Lifeboat." The inventors claim for it advantages which no other lifeboat possesses, viz., that it can neither capsize after being launched from a vessel's deck, nor can it sink. As its name implies, it is top and bottom both alike, and if in launching, before it touches the water, it should, by the rolling of the vessel, or any other cause, turn over, there are thwarts and seats running round the side just the same as there would have been had the boat gone in the other way up. Whichever side the lifeboat takes the water, when she is once afloat, a couple of flaps running the whole length will close and form the bottom of the boat, and there is provision for drawing a further flooring out, which will rest upon strong beams. The boat receives its unusual buoyancy from a massive belt of cork, which is encased in canvas, and runs from stem to stern on each side, and forty separate air-tight tanks, ten on each side of both the upper and lower part of the boat. Still further buoyancy is obtained by large tanks at each end of the boat, but it is intended to use these latter compartments as store-rooms, in which may always be kept a stock of provisions, spirits, clothes, medicines, water, &c., the whole supply being protected from damage by either rain or sea water. On each side of the belt of cork outside the boat there are numerous life-lines, which will hang in the water, so that anyone falling overboard on leaving a vessel may readily gain the boat and hoist themselves on board. In addition to this, there are lashed along what is intended to be the upper side of the boat as it stands on the vessel's deck, twelve cork life-buoys, six on each side, and should the boat in launching fall the other side up the life-buoys will disengage themselves and come to the surface, being equally available as they would have been had the boat not turned over. Captain Burkinshaw estimates that a boat of this kind, 30 ft. long, will save at least 120 persons, either inside of her or standing upon the cork belt. It is intended that it shall be kept on deck, or on a hatchway even, and that a tram line shall be placed from the boat's berth to the nearest gangway, by which means the boat can be launched without fear of any accidents with tackle falls, which in the hurry of leaving a sinking ship have so often been attended with fatal consequences.—*Hull News.*

Thompson's Patent Life-Raft.—Now that the ingenuity of inventors is fairly enlisted in the cause, we may confidently expect that some thoroughly effective and practical device or devices will be perfected for saving life at sea. In cases of shipwreck, as has been markedly shown in some recent and fatal catastrophes, the excessive loss of life is mainly owing to two conditions—the want of a sufficient number of boats for the rescue of the survivors, and the difficulty of launching those that are on board in a seaworthy condition. By the present invention, both of these desiderata are in a great measure supplied. We have first an easy and safe mode of launching life-boats in states of the weather when it is dangerous, if not impossible, to put them to sea by any other method; and, secondly, the launching apparatus itself is capable of being utilized into an effective life-raft, large enough to accommodate, perhaps, twice as many cast-a-ways as the life-boat could receive. The boat is on ways and rollers, and can, in consequence, be launched without difficulty on either side of the ship. The shipping of water during the process of launching is prevented by covering her forepart with canvas, so that her crew, unless under very exceptional circumstances, may be lowered with her. Otherwise a connection may be maintained with the ship by means of a long rope. After the life-boat is launched the raft may be got overboard in the same way, but without her crew. When on board ship it forms a bridge, and may be carried above a sailing ship's deck before the main hatch or abaft the after one. It rests on stanchions, the side ones being lowering ones. A simple movement of a lever when the boat or raft is required for use withdraws the sustaining ones, and the stanchions with the raft fall down to the top-gallant rail, giving the latter an angle of 30 deg. The cost of the raft will scarcely, if at all, exceed that of a life-boat, and by the new Shipping Bill it will count in lieu of one.

Recently a trial of one of these rafts was made at the yard of Messrs. Money Wigram & Co., Poplar, in the presence of a great number of interested persons, including Admiral Sir Alexander Milne, and one or two other representatives of the Admiralty. A raft was fitted up on the shore, to imitate, as far as possible, the bridge of a vessel, with a boat upon it. This boat was launched first, but, unfortunately (being one which had been selected at hazard, and not a life-boat) it capsized, the five men who were in it being thrown into the water. Four of them were rescued very quickly; the fifth, who was under the capsized boat, was not picked up for some minutes, owing to the difficulty of righting the boat. The launch of the raft itself was most successful. It was tested with the weight of sixty-five men, who also rolled it from side to side, without upsetting it. We understand that the Admiralty authorities have expressed their perfect satisfaction with Mr. Thompson's raft.—*Iron.*

BOOK NOTICES.

THE RUDIMENTS OF PRACTICAL BRICKLAYING. By ADAM HAMMOND. London: Lockwood & Co. For sale by Van Nostrand. Price 60 cts.

This little treatise is a late edition of the "Weale Series." It embraces the following practical subjects:

General Principles of Bricklaying—Drawing, Cutting, and Setting Arches—Different Kinds of Pointing—Paving, Tiling, Use of Materials, etc.—Slaters' and Plasterers' Work—Practical Geometry and Mensuration.

Some fifty woodcuts illustrate the text.

THE PRACTICAL MILLWRIGHTS' AND ENGINEERS' READY RECKONER. BY THOMAS DIXON. Fourth Edition. For sale by Van Nostrand. Price $1.25.

In this handy book there are tables for finding the diameter and power of cog-wheels, the diameter, weight, and power of shafts, the diameter and strength of bolts, tables of circumferences and areas of circles, of weights and measures, and other arithmetical details in constant requirement by engineers and millwrights, all being very clearly arranged for reference, and comprised in a volume of suitable size for the pocket.

BUTTER: ITS ANALYSIS AND ADULTERATIONS. By ARTHUR ANGELL, F. R. M. S., and OTTO HEHNER. London: Wyman & Sons. For sale by Van Nostrand. Price $1.50.

The detection and estimation of foreign fats is the special topic of this little manual. The subjects treated by chapters are as follows:

I. The Composition of Butter.
II. The Determination of the Constituents of Butter.
III. The Microscopic Examination of Butter.
IV. The Fusing Point.
V. The Analysis of Butter Fat.

There can be no doubt about the usefulness of this new manual.

DETERMINATION AND CLASSIFICATION OF MINERALS. By JAMES C. FOYE, A. M. Chicago: Jansen, McClurg & Co. For sale by Van Nostrand. Price 75 cts.

The object of the author as set forth in his preface, has been to furnish tables by which the student may, with as few easy tests as possible, determine with precision and classify minerals found in the United States, and become familiar with their principal characteristics.

The plan includes examinations with blowpipe, with nitric sulphuric and hydrochloric acids, and tests for hardness and specific gravity.

It is exceedingly compact and we doubt not excellent.

AN EASY INTRODUCTION TO CHEMISTRY. By ARTHUR RIGG, M. A., and WALTER GOOLDEN, B. A. London: Rivington's. For sale by Van Nostrand. Price $1.25.

We can recommend this book to readers who desire to obtain a good idea of the great fundamental principles of chemistry, without the necssity of acquiring its technical nomenclature.

The experiments employed in the lecture-room to illustrate leading principles are clearly described; the chemistry of every day life is judiciously presented and the whole offered in an attractive garb. The illustrations are good and numerous enough. To solve the problem of presenting an outline of chemical science in 150 pages we do not see how it could be better done than in this little book.

THE LIVES OF THE ENGINEERS. By SAMUEL SMILES. New and revised edition. London: John Murray. 1874. For sale by D. Van Nostrand. Price $18.75.

Mr. Smiles' work is too well known to require criticism now at our hands, and little need be said about the present edition except to compliment Mr. Murray on the style in which he has given the book to the public. The whole, apparently unabridged, is contained in five handsome octavo volumes, beautifully printed on excellent paper, and very tastefully bound. The illustrations are not only admirable in themselves, but printed, with a very few exceptions, in perfection. It is beyond our power to say how many editions the work has reached, but we are quite certain that not one on the whole more satisfactory has yet been been published.

NOTES ON BUILDING CONSTRUCTION. Part I. Elementary course. London, Oxford and Cambridge: Rivington's. For sale by Van Nostrand. Price $5.25.

The work is designed when complete to meet the requirements of the syllabus of the science and art department of the committee of council on education at South Kensington.

Two more volumes or parts are soon to follow. Part II. will be devoted to the "Advanced Course," and Part III. will contain investigation of stresses or parts of structures, the nature and applications of materials, etc.

The present Part treats exhaustively and clearly and with abundance of good diagrams of Walling and Arches—Brickwork—Masonry—Carpentry — Floors — Partitions — Timber Roofs—Iron Roofs—Slating—Plumbers' Work—Cast Iron Girders and Cantilevers—Joinery.

It is a fine octavo volume of 220 pages, with 325 woodcuts.

THE PAPER AND PROCEEDINGS OF THE U.S. NAVAL INSTITUTE. New York: D. Van Nostrand. Volume I, (1874) contains the following contributions: 1. "The Manning of our Navy and Mercantile Marine," by Capt. S. B. Luce, U. S. N. 2. "The Cruise of the Tigress," by Lieut. Com. H. C. White, U. S. N. 3. "Compound Engines," by Chief Engineer C. H. Baker, U. S. N. 4. "The Compass," by Prof. B. F. Greene. 5. "The Armament of our Ships of War," by Capt. U. N. Jeffers, U. S. N. 6. "The Isthmus of Darien and Interoceanic Canal," by Lieut. Fred Collins, U. S. N. 7. "Centre of Gravity of the U. S. Steamer Shawmut," by Naval Constructor T. D. Wilson, U. S. N. 8. "Fleet Manœuvres and the Navy of the Future, by Com. F. A. Parker, U. S. N. Price $2.

HANDRAILING. By JOHN JONES. London: E. & F. N. Spon. For sale by Van Nostrand. Price $2.50.

This treatise exhibits the advantage of others on this branch of building of presenting the method of designing on a large folio page. The diagrams thus drawn are unmistakably clear, and the space admits of the exhibition of all the auxiliary lines required by the draughtsman.

Such a work is often sought for by architectural students.

A RECORD OF THE VIENNA EXPOSITION OF 1873. Atlas of Plates. By WM. H. MARO and JAMES DREDGE. London: Office of Engineering. For sale by Van Nostrand. Price $50.00.

The above plates have mostly appeared in Engineering during the last twenty months. They are now collected in a single large folio volume, printed on tinted paper. They are, as our readers probably know, presented in such form, and with such elaboration of detail, as to supersede the necessity of separate text.

They illustrate recent progress in every branch of civil or military engineering and agriculture.

CLIMATE AND TIME. By JAMES CROLL. London: Dalby, Isbister & Co. For sale by Van Nostrand. Price $12.00.

The discussion of the causes of the Glacial Epoch, and the more genial Carboniferous Period, has received an important contribution by this elegant work from the pen of an active geological worker.

Oceanic circulation receives its full share of attention, and the late somewhat sharp discussions in scientific journals are reviewed with care and skill.

The work is a valuable contribution to the literature of physical geography.

REED'S HEAD-LIGHT. By WM. H. REED, M.E. Price $2.50.

This is specially designed for locomotive engineers and machinists. It contains, besides explanations of the technical terms, numerous valve-tables of link motions. Mensuration tables and a little outline of practical geometry occupy a fair amount of space.

The few illustrations look disproportionately large for the page, but they possess the merit of clearness, and answering fully the designed purpose.

A MANUAL OF FRET CUTTING AND WOOD CARVING. By Maj. Gen. Sir THOMAS SETON, K. C. B. London: Geo. Routledge & Sons. For sale by Van Nostrand. Price $1 00.

A neatly printed and illustrated book of 150 pages, written for boys; describes the whole art of wood carving from the first use of tools to the designing of intricate compositions. T style is remarkably plain, and the difficulties the beginner meets with are anticipated.

The book will prove useful to many a boy who amuses himself with wood working without aspiring to the art of carving.

USEFUL TABLES. By W. H NOBLE, London. For sale by Van Nostrand. Price 25 cts.

The contents of this minute volume comprise tables for conversion of French in English units and *vice versa;* lines and tangents to four places and logarithms of numbers to four places of decimals. These are neatly printed on a page of 4 by 3½ inches. A convenient size for the pocket.

THE SAILOR'S POCKET-BOOK. By Commander F. G. D. BEDFORD, R. N. London: J. Griffen & Co. For sale by Van Nostrand. Price $3 75.

The topics discussed in this convenient little volume are Signals—The Compass—Rule of the Road—Law of Storms and Meteoroligical Instruments—Lights, Buoys, and Determination of Position—Boats and their Management—Operations on Shore—Loading, Bivouac, and Attack—Life - Saving Apparatus—Currency, Weights, and Measures of Different Nations—Miscellaneous Tables, Practical Recipes, etc.

By judicious exercise of brevity much information is crowded into a small space. It is not necessary to be a sailor to gain much valuable information from these pages.

QUALITATIVE CHEMICAL ANALYSIS. By Prof. SILAS H. DOUGLAS and Prof. ALBERT B. PRESCOTT. Ann Arbor. Price $3.50.

Both the authors of this new work are experienced instructors and have brought a rare degree of skill to bear on the construction of this manual. The notation is modern, as is also the order in numbering the groups of bases, the silver group being placed first. In the tables for "separation" we notice a valuable feature—it is the addition of confirmatory tests of any base to the described routine of separating it from the members of its group, given directly and briefly in the columns of the table. A table of solubilities of the metallic salts, as also a list of commonly occurring salts with their *degree* of solubility form valuable additions to the ordinary matter of such manuals.

It will rank with the larger works on analysis in the extent and accuracy of treatment of this branch of practical science.

THE ARTISAN'S GUIDE. By R. MOORE. Montreal: Lovell Publishing Co. Price $2.00.

A collection of all the practical receipts that have been published for some years, without regard to their genuineness, is what this book appears to be. That the editors' ideas of classification are not very strict may be inferred from the contents of page 59 for example; this presents among other things directions for making emery wheels, making laughing gas, and cure for lockjaw.

The chemical processes on this page are not above suspicion. Take this for instance—where the writer gives a second method for making laughing gas—"by pouring nitric acid, diluted with five or six times its weight of water, on copper filings or small pieces of tin!" We would suggest as a useful addition to this page of miscellaneons rules to be observed in impanneling a coroner's jury, to follow in future editions the above directions for making laughing gas.

The directions for inhaling this gas given also on page 59 are not easy to follow. The clearness is not obtrusive. Here it is: "Procure an oiled or varnished silk bag or bladder, furnished with a stop cock, into the mouth, and at the same time hold the nostrils, the sensations," etc.

As this page was taken quite at random, it is quite possible that among the 470 pages, there are more of like value.

GUIDE PRACTIQUE DE TELEGRAPHIE. By LOUIS HOZEAN, *employé des liques telegraphiques.* Paris: E. Dentu, 1874. New York: D. Van Nostrand. Price $1.20.

This work is designed for the use of students, and as a practical guide for telegraphic employees, and is intended to occupy much the same ground in relation to the French telegraphic system, that Pope's "Modern Practice" does to the American. It commences with a description of the essential portions of the apparatus and their functions, and then treats of the laws of the current, so far as is necessary to a clear understanding of the operation of the instruments, which is followed by a concise description of the construction and operation of the switch or commutator, the galvanometer, the lightning arrester, and other less important adjuncts to the telegraphic apparatus proper. Other chapters give directions in regard to the adjustment of the instruments, the establishment of stations, the manipulation of the key, and formation of Morse alphabet, etc., etc. The appendix contains an essay on the different kinds of batteries and their management. One ingenious feature of the book is a (presumably) complete list of all the ills that telegraph instruments are heir to, systematically arranged in tabular form for convenience of reference. The book is written, of course, with reference to the French method of working the Morse apparatus, and, therefore, would perhaps be of little use to the average American operator, especially as it is printed in the French language. To those, however, who are interested to know how the French telegraphs are actually worked, it will prove of value. The work is beautifully printed, and the execution of the numerous illustrations, which are original drawings on wood, by the author, is simply superb.—*The Telegrapher.*

IRON AND TIMBER RAILWAY SUPERSTRUCTURES AND GENERAL WORKS; WITH SOME EARTHWORK TABLES AND OUTLINE OF SPECIFICATION AND REQUIREMENTS. By J. W. GROVER, M. Inst. C. E. For sale by Van Nostrand. Price $17.00.

The work under this title, by Mr. Grover, is intended as a continuation of the author's previous work, "Estimates and Diagrams of Railway Bridges, Culverts, and Stations." The object of the work is to afford the engineer concise information in a portable form, to assist him in framing rapidly his reports and estimates, especially in regard to the probability of the employment of other (lighter) gauges than the present standard one of 4 ft. 8½ in. In the notes to each diagram the quantities, weights, and rolling and fixed loads are given in each case, so as to admit of estimates and comparisons being made with facility. The diagrams, which, without any pretension to high finish, are very accurately and carefully made out and figured, include details for ordinary bridges of various spans, calculated in some cases for mètre gauge, though in the majority for standard gauge; diagrams of iron girders for various spans; a general abutment diagram; timber bridges for straight and curved routes; gates, fencings, and other adjuncts of railway finishing work. An outline or model specification is appended, for the "works necessary for the construction of the A and B Railway," which will serve very useful purpose as a general memorandum in drawing up a specification, and may enable the engineer to turn over the specifying in general cases, and where there are no special difficulties, to subordinates, without fear of any necessary provision being overlooked. The table for rapidly computing amounts of earthworks, on the basis of rough sections of the site of the line, is calculated to save much time in making estimates, where the character of the work is tolerably similar over a large extent of line.

The diagrams given are taken mostly from works designed for actual execution, many of them having been carried out by the author and others. The iron-work is given with details and weights, so as to be practically available for manufacturers and contractors. The author believes that "the examples in this volume, taken with those already referred to in his preceding treatise, will cover those superstructures most generally required in actual practice in their primary forms."

Looking at it from an architect's point of view, it is noticeable into what effective and picturesque forms timber structure fall, even when designed on the most strictly economic and practical principles. Some of the timber viaducts shown here want very little to be objects of real beauty and interest. The same cannot be said of the iron structures. If it is possible to render iron railway bridges otherwise than hideous, the manner of accomplishing it has scarcely been hit upon as yet.

HYDRAULIC TABLES, CO-EFFICIENTS, AND FORMULÆ, FOR FINDING THE DISCHARGE OF WATER FROM ORIFICES, NOTCHES, WEIRS, PIPES AND RIVERS. By JOHN NEVILLE, C.E., M.R.I.A., &c. Third edition. London: Lockwood & Co. For sale by D. Van Nostrand. Price $7.00.

That table and formulæ facilitate the compression of a large amount of information into a very small space is acknowledged by all practical men, but it is essential that their application should be thoroughly understood in order to prevent conclusions being drawn which are not justifiable; it is for this reason that special value attaches to the volume of Mr. John Neville, in which the tables, &c., are introduced by so complete a treatise upon the subject that the facts will be well impressed upon the memory, or if the memory fail upon any particular point it can be readily refreshed. In the present edition several new formulæ, experimental co-efficients, and general estimates of cost have been inserted, which no doubt render the book more useful than before to meet the ever varying requirements of the profession, in connection with rivers and waterworks. Referring to the practice of giving only two-thirds of the co-efficient of discharge for weirs, Mr. Neville remarks that this practice assumes that the theoretical discharge from a notch is the same as if all the particles of water had the same mean theoretical velocity as those undermost, which, being too large by one-third, the experimental co-efficient has to be reduced in the same proportion to give a correct result. There is no reason, he remarks, for sanctioning a different co-efficient for notches or orifices at the surface and for sunk orifices. The co-efficients, when in thin plates with large cisterns, have nearly the same general value—.615 to .628 for both—and it tends to confusion to adopt in one place a co-efficient for a correct formulæ, and in another a co-efficient for an incorrect one, although the final result by an equality of contrary errors may be the same. He observes how very general the co-efficient of two-thirds and thereabouts is for all orifices and notches, likewise for the useful effect derived from the application of water-power; as well, also, for the relation of the velocity due to the fall, and the velocity of water-wheels to give a maximum result; and remarks that the modification of co-efficients dependent upon the position, thickness, form, and approaches of an orifice are as yet little understood by the profession. The defects in the ordinary formulæ when the velocity of approach has to be considered are carefully pointed out, and he very truly states that before the effective power of a water-wheel or water-engine can be determined we must know how to gauge the water supplied to it correctly, adding that this can only be done by the application of formulæ and co-efficients varied to suit the circumstances of the case under consideration.

The sections, 15 in number, into which Mr. Neville has divided his book, really meet all the cases which are likely to occur in practice, explaining, amongst other things, the extra horse-power required in pumping-engines from friction in the pipes, the variations in the co-efficients from the position of the orifice, the circumstances to be considered in connection with submerged orifices and weirs, and with contracted river channels, best forms of the channels, different losses of head, and so on, corresponding tables being given for the several sections, so as to enable the reader or student to apply the rules given, and obtain the desired results with the least possible trouble and calculation. The work, which is now printed in convenient size, and has been much augmented by the insertion of new formulæ for the discharge from tidal and flood sluices and syphons, and general information on rainfall, catchment basins, drainage, sewerage, water supply for towns, and mill power, will prove alike valuable to students and engineers in practice; its study will prevent the annoyance of avoidable failures, and assist them to select the readiest means of successfully carrying out any given work connected with hydraulic engineering.—*Mining Journal.*

The Practical Assayer, containing easy methods for the assay of the principal metals and alloys. Oliver North. London: Chatto & Windus. For sale by Van Nostrand. Price $3.75.

Reference was some time since made to the publication of a selection of easy methods for the assay of the principal metals and alloys by Oliver North (Mr. Hugo Cookesley), and as the book was especially designed for explorers and those interested in mines, so further particulars of its contents may not be unacceptable. The author explains that his object was to provide a want he long felt himself—a concise and clear account of the best and quickest way of assaying the principal metals. He considers that the province of the analytical chemist is totally distinct from that of the assayer; that analytical chemistry presupposes as a primary condition that the operator should be a chemist, whereas assaying is a mere mechanical art, depending almost entirely on manipulation. To some extent these views are correct, but it must not be supposed that an assayer without chemical knowledge can do more than follow a beaten track, or that he can hope to succeed with ores possessing any special peculiarities: facility to deal with the commonly occurring ore will, however, for many be sufficient. The information given is at once concise and thoroughly intelligible, and embraces instructions for the assay of copper, silver, gold, tin, lead, iron, zinc, bismuth, nickel and cobalt, sulphur, arsenic, nitrate of soda, and guano, so that the mining assayer will care for little more. All description of assays of copper by the dry way has been omitted because they are rough and uncertain, inaccurate, and never give the true result even by the most careful manipulation. The precipitation process, practised almost universally, and brought to really surprising degree of accuracy in Chili, is given as the most convenient. The assays of silver ores by running them down in a crucible with suitable flux, by scorification, and by the blowpipe are explained, as are also the modes of determining alloys of silver and copper; there are likewise some good general observations on the assay of silver ores, and on the operation of cupellation; a dozen pages being then devoted to the assay by the wet way, which is quite easy and much more useful. The assaying of gold quartz, the determination of alloys of gold and copper, and the parting of gold and silver are explained. Referring to the assay of tin, it is remarked that the only methed of asaying tin ore is by the dry process, several modifications of which are carefully detailed; and the mode of estimating alloys of tin with iron, tungsten, &c., is described. For the assay of lead, the method usually practised and commended at the School of Mines is given, and there are full particulars as to the estimation of iron, zinc, mercury, and manganese, it being remarked with regard to the latter that the value of the ores of manganese entirely depends on their relative power of evolving chlorine. The amount also of some foreign bodies, notably protoxyde of iron, should also be estimated, as these diminish the value of the ore; the methods of Will and Fresenius and of Graham are given as the most practical. The remarks upon the assay of bismuth are followed by an account of Tamm's method for purifying that metal from copper, arsenic, antimony, and sulphur. There is also a description of Pearson's process for assaying bismuth by volume. For the assay of nickel and cobalt several processes are given, but it is explained that of these the half wet and half dry process described is the only really reliable one. The assay of sulphur and arsenic are concisely explained, and, as already stated, that of nitrate of soda and guano also; the volume being concluded by a series of useful tables for determining the standard of silver alloy, and for showing the amount of gold and silver in the ton from a 200 grain assay.

Throughout the book there is undoubted evidence that the author has had extensive practice in his profession, and that he has a very ready and agreeable way of imparting his information to others will be ackowledged by all who read it. It appears to be thoroughly reliable, and at the same time very compact and portable, so that it is worthy of extensive adoption among the class for whom it is intended.

PRACTICAL GUIDE TO THE DETERMINATION OF MINERALS BY THE BLOWPIPE. By Dr. C. W. C. FUCHS. Translated and edited by T. W. DANBY, M. A., F.G.S. London: Field & Tuer. Price $2.50.

The general recognition in almost every branch of industry of the value of at least an elementary knowledge of mineralogy, owing to the facility which it gives for estimating the quality or purity of one or other of the materials used in the processes employed, has led to very numerous efforts being made to furnish a reliable and rapid means for the determination of salts and minerals, and from the extreme portability and compactness of the complete apparatus for the performance of blowpipe analysis that method has received a large amount of attention. For the two leading arrangements for placing the means of determination, especially qualitative, within the reach of practical men and comparatively inexperienced students, the world is indebted to Germans—those of Franz von Kobell, of Munich, and Prof. Fuchs, of Heidelberg, the latter being, in fact, a modification of the former—being each recognized as excellent, as indeed may be judged of from the circumstance that Franz von Kobell's book, the tenth edition of which was reached in 1873, has been translated into several languages, whilst Fuch's, which was published in 1868, has been ably translated into French (Guide Pratique pour la Determination des Mineraux) by Aug. Guerout, and the second translation into English has now been issued by Mr. T. W. Danby, of Downing College, Cambridge. The first translation into English, that of Prof. G. W. Plympton, of the Polytechnic Institute, of Brooklyn, New York (New York: Van Nostrand, London: Trubner) was fully noticed in the *Mining Journal* of Nov. 28 last, differs from that of Mr. Danby, inasmuch as Prof. Plympton has given the new chemical notation, which is also adopted in the later editions of Von Kobell, whilst Mr. Danby retains the old, which with many of the older mineralogists is still preferred.

In place of the second part of Fuch's book Mr. Danby has given a table of far greater practical utility, showing the hardness, specific gravity, and crystallographical system of each species so far as the latter are determined beyond question; and it is almost to be regretted he did not adopt the admirable appendix given by Prof. Plympton to assist the less experienced student with regard to certain difficulties usually met with. Prof. Plympton's appendix describes a method of distinguishing the red flame of lithia from that of strontia; the reduction of maganese salts on baryta, the detection of baryta in the presence of strontia, the action of baryte on titanic acid, the detection of oxide of manganese when present in minuta quantity in mineral bodies, the method of distinguishing protoxide of iron from peroxide of iron in silicates and other compounds, the detection of minute traces of copper in iron pyrites and other bodies, the detection of lead in the presence of bismuth, and the detection of antimony in tube sublimates. These details are chiefly from the published notes of Prof. Chapman, of Toronto. A not less interesting article given by Prof. Plympton is an account of Mr. Landauer's neat application of chlorate of potassa as a reagent. The action of this salt is of course that of energetic oxidation caused by the evolution of oxygen at a high temperature.

The detection of the oxides of the metals below is readily affected by the following means. In a tube 15 centim. long and 5 millim. in diameter closed at one end place the test substance together with a small quantity of chlorate, apply heat gradually at first without, and then with, the help of the blowpipe until no more oxygen is given off. The reaction is then completed, and the color of the test is to be examined; flesh color denotes the presence of iron; yellowish brown, lead; black, or greyish black, copper; blue to black, cobalt; purple, manganese; black, nickel. Such details as these certainly appear calculated to prove of great utility to the class for whom Mr. Danby's book is written, and it is, therefore, to be hoped they will be incorporated when a second edition is issued.

Mr. Danby appears to have done full justice to Prof. Fuchs in the translation, which will, no doubt, be extensively adopted, since the classification of the several minerals according to their behavior on charcoal, whether they volatilize or burn, emit a given odor, give off fumes of antimony, coat the charcoal, or leave a characteristic residue, and so on, renders it extremely easy to find the group to which a mineral under examination belongs, and scarcely more difficult to determine which particular member of the group it is. The arrangement is at once simple, reliable, and concise; and as the volume has been interleaved so as to serve for a note-book as well as a guide-book, a more useful companion in the field could scarcely be wished for.—*Mining Journal.*

MISCELLANEOUS.

PERUVIAN METALS AND JEWELS.—A report from our consul at Islay states that the inauguration, in 1870, of about 108 miles of appropriate railway from the projected port of Mollendo to Arequipa has most beneficially operated on the country, and the comparatively trivial line of communication really marks the era of a totally new national life. The greatest mineral, vegetable, and pastoral resources of this country, which are enormous, are to be found far inland and converging upon the departmental cities of Arequipa, Pano, Cuzco, and Moquegua, hitherto cut off from the Pacific coast by the breadth of an arid and seemingly inhospitable tract stretching westward from the Corderillas, and measuring 100 miles more or less, which has afforded no other means of transit but sumpter-mules, and which has been chiefly dependent for the necessaries of life upon the navigation upon the coast.

Immigration of foreign operatives, peasantry, and small settlers has not been promoted. The two coasting provinces of the Arequipa department, namely, those of Camuna and Islay, are reported to be little better than a parched desert, intersected by seven rivers and some trifling streams, all running westward and south-westward from the Corderillas to the ocean through the deep ravines which the snow waters have hollowed out across the Pampa and the sandy decline, and in most, if not all, of which fine gold wash is to be found. The mountain territory already traversed, or to be traversed, by the railway forms, so to speak, an irregular basin and mineral receptacle in the chain of the Andes, in different parts of which the precious metals, including platinum and highly-prized jewels, such as the diamond, sapphire, and emerald, do exist in fair quantities, and under very favorable conditions for exhumation, in a country not more remote from the equator than from 13° to 17° south, and yet tempered by an elevation mostly of 10,000 feet and upwards, and by the vicinity of perpetual snow. It is true that not much heretofore has been made of these resources, and the famous Mina del Manto, near Pano, has been abandoned, even by English adventurers, because they could not transport the machinery they wanted to the spot, and because they were too insecure in many respects now totally changed. Setting aside the secret proceedings of the Indians, which are too occult to be more than alluded to, it is also true that there have been very limited gold workings in the territories of Cavabaya and Pancartambo, besides some desultory washings in the neighborhood of Cuzco; but it must be borne in mind that the natives, including those of Spanish descent, in the interior are mostly inert by habit, and recent research leads to the conviction that the richest districts no less than the vitreous, black and red varieties of the silver ore, and platinum, have been overlooked by those few Europeans who have visited the interior.

As it would appear that the resources of this part of Peru, under the head of gems, have been somewhat neglected, it may be useful to notice the remarkable presence of emerald of the purest water and largest crystals (as the valued form, rather than species, of the beryl, otherwise abundant elsewhere). In the veins and fissures of granitic primitive rocks, and associated with quartz, felspar, and mica slate, this gem is here distributed freely in crystals of various dimensions usually of very fine color, and often without flaw if carefully abstracted, the test by heat being simple.

Iron ore of superior quality is to be found—by parity of reasoning in reference to surroundings—in profitably and usefully available quantities.

Traces of coal have already been revealed in the form of a kind of carbonized and ligneous conglomerate and consolidated peat, of a dull brownish shade, and partially conchoidal fracture, leading to favorable deductions.—*Iron.*

FROM some statistics taken from a report recently published by the Minister of Commerce, it appears that there are in France no less than 123,000 manufacturing establishments employing 502,000-horse-power and 1,800,000 work-people. The department of the Seine figures first on the list for a production amounting in value annually to 1,690 millions of francs, or about one-fifth of the total production of France. The Department Du Nord is the next in importance with a production to the value of 700 millions, the department of the Rhone to the value of 600 millions; the Seine inferieure for 440 millions, the Bouches du Rhone for 271 millions, and the department of the Noire for 224 millions; in the other departments the value of the products of manufacturing industry is considerably less, but the average per department is estimated at 100½ millions of francs per annum.

THE following is Mr. Heeren's process for giving iron wire the appearance of silver. This is done by a thin film of tin. The iron wire is first placed in hydrochloric acid, in which is suspended a piece of zinc. It is afterwards placed in contact with a strip of zinc in a bath of two parts tartaric acid dissolved in 100 parts of water, to which is added three parts of tin salt and three parts of soda. The wire should remain about two hours in this bath and then be removed, and made bright for polishing, or drawing through a polishing iron. By this galvanic method of tinning, wire which has been wound in a spiral, or iron of other shape, can be made quite white, which is an advantage over most other methods, where the wire is tinned in the fire and then drawn through a drawing plate.